Vol. 10 No. 5

May, 1944

THE BOTANICAL REVIEW

Interpreting Botanical Progress

Control of Noxious Plants ..... H. K. WILSON 279

IMPERIAL MYCOLOGICAL INSTITUTE
7 DEC 1945

PROPOSED FUTURE CONTENTS ON REAR COVER

Published Monthly except August and September at
North Queen St. and McGovern Ave., Lancaster, Pa.

Entered as second-class mail matter February 4, 1935, at the Post Office at Lancaster, Pennsylvania, under the Act of March 3, 1879.

THE BOTANICAL REVIEW

Founded in 1935 by
H. A. GLEASON AND E. H. FULLING
Managed, edited and published at
The New York Botanical Garden
by
E. H. FULLING

Advisory Editors

PROF. R. W. CHANEY, paleobotany
PROF. W. S. COOPER, ecology
PROF. A. J. EAMES, morphology
PROF. E. M. GILBERT, mycology
DR. A. F. HILL, economic botany
DR. F. W. PENNELL, taxonomy
PROF. CONWAY ZIRKLE, cytology
DR. M. M. RHOADES, genetics
PROF. GILBERT SMITH, phycology
PROF. N. E. STEVENS, pathology
PROF. S. F. TRELEASE. physiology

THE BOTANICAL REVIEW is published monthly except August and September. Subscription rate for the United States is $4.00 per year; for Canada and other foreign countries $4.25; single copies, 50¢. All subscriptions are payable in advance at par in Lancaster, Pa., or New York. Checks should be made payable to THE BOTANICAL REVIEW.

Manuscripts are prepared by contributing authors only upon invitation and on the suggestion or with the approval of the advisory editor in whose field the subject lies. Unsolicited manuscripts will not be considered. The editor, nevertheless, welcomes suggestions of topics which might properly be reviewed.

Missing numbers can not be supplied unless notice is received within two months after appearance of issues concerned.

All correspondence should be addressed to THE BOTANICAL REVIEW, at N. Queen St. and McGovern Ave., Lancaster, Pa., or Fordham P. O., New York, N. Y.

THE BOTANICAL REVIEW

VOL. X MAY, 1944 No. 5

CONTROL OF NOXIOUS PLANTS[1]

H. K. WILSON[2]
University of Minnesota

INTRODUCTION

This discussion centers around those plants which are considered to be weeds. A weed, according to one authority (137), is a plant growing where it is desired that something else shall grow; according to another (294), it is "A plant that does more harm than good and has the habit of intruding where not wanted". A noxious plant is a weed that is especially undesirable because of certain attributes of it which prevent associated crop plants from attaining normal productivity. These undesirable traits may be of several types. The principal ones are persistence and vigor of growth, poisonous properties of herbage or fruits, and possession of spines or thorns injurious to animals. Other characteristics for a plant being classed as noxious may be advanced, but those listed include most weedy plants.

Few people realize the extreme seriousness of weeds. Too many take weedy plants for granted as necessary evils that we must endure, and because of their universality do not appreciate the damages done. The United States Chamber of Commerce (61) estimates the annual losses from weeds as compared with the more spectacular livestock diseases and insect pests as follows:

Diseases and plant poisoning of live stock..	$ 250,000,000
Insect pests	1,000,000,000
Weedy plants	3,000,000,000

In other words, weeds occasion greater losses than the other two groups of pests combined. However, the great amounts spent in

[1] Received for publication Sept. 7, 1943. Paper No. 2109 of the Scientific Journal Series, Minnesota Agricultural Experiment Station.

[2] Agronomist, Division of Agronomy and Plant Genetics, Minnesota Agricultural Experiment Station. The writer expresses his thanks to Dr. H. K. Hayes, Chief of the Division of Agronomy and Plant Genetics, University of Minnesota, for suggestions and criticisms during the preparation of this manuscript.

combatting animal diseases or insects by far exceed the funds expended on weed control research. It would appear that the principal reason for this anomaly lies in a lack of appreciation of the seriousness of the weed problem.

Some weedy plants are poisonous to animals which consume them because they either contain poisonous compounds or produce poisons in the animal's digestive system. Most such losses occur in the western states where poisonous plants are more abundant than in the East. Injury of often as much as 8% of Colorado's livestock results from the effects of more than 100 species of such plants (118). Significant publications on poisonous plants are indicated in citations Nos. 70, 135, 145, 193, 239, 241, 280, 325, 326, 359, 363, and 371.

Many common weeds possess sharp structures as awns, thorns or barbs which may cause mechanical injury to livestock (197, 282, 362). In certain areas of the West, sheep may have such sore mouths as a result of them that they are unable to eat. Frequently eye wounds result in partial blindness which prevents their finding feed. Certain types of needle grasses may become imbedded in the flesh of sheep, and this materially lowers the quality of the carcass. A few of the more common weeds producing mechanical injuries are wild oats (*Avena fatua* L.), wild barley (*Hordeum jubatum* L.), puncture vine (*Tribulus terrestris* L.), sandbur (*Cenchrus pauciflorus* Benth.) and species of *Xanthium, Cirsium, Centaurea, Aristida* and *Stipa*.

Some weedy plants impart undesirable flavors and odors to the dairy products of cows which eat them (159), and millions of dollars are thus lost each year. The more common weeds producing bad flavors are species of *Allium,* including wild onion, garlic and leek. The Frenchweed plant (*Thlaspi arvense* L.) produces a similar flavor. Other weeds which impart undesirable flavors to milk are pepper grasses, wild carrot, ragweeds, marsh elder, smartweeds, mustards and bitterweed (*Helenium tenuifolium* Nutt.). Walker (386) found that removal of dairy cows at least three hours before milking from pastures containing milk-tainting weeds prevented contamination.

In some sections of the East wild garlic grows in wheat fields and the bulblets are harvested along with the wheat. Unless the bulblets are separated the garlic imparts a flavor to the flour, thus reducing its market value.

Poison ivy (*Rhus toxicodendron* L.) and poison sumac (*Rhus Vernix* L.) are examples of weedy plants which may cause a severe itching rash on the skin of most persons. Some people are resistant or immune; others are very susceptible. Much time is lost each year by those who are infected, and in some cases complications result in death. Grand and Hansen (147) and Yeager and Calahan (406) give control measures.

Hayfever causes losses of millions of dollars each year and makes life somewhat miserable for thousands of citizens. Probably the most common cause is the pollen of the common ragweed (*Ambrosia elatior* L.). Few areas of the country are free from its pollen and these sections become havens of refuge during late summer when the plants are in bloom.

Weeds harbor numerous parasites and diseases. Sallans (324) notes the relationship between weeds in cereals and development of root-rots, while Wallace and Murphy (387) report on certain weeds which harbor sugar-beet diseases. Some weeds appear to be carriers of leaf-roll and rugose mosaic of potato (119), and the cotton root-rot fungus, *Phymatotrichum omnivorum* (Sh.) Dug., lives on many species (318). Piemeisel (293) reports on the relationship between weedy plants of Idaho and the curly top disease.

Investigating the probable effect of weeds on soil fertility, Snidor (351) analyzed 15 common species in central and northern Illinois. The percentage of nitrogen, phosphorus, potash, calcium, magnesium, iron and manganese compared favorably with that of various crop plants such as alfalfa, clover, timothy, red top, corn stalks and wheat straw. Weeds feed heavily and utilize fertility which would otherwise be available for competing crop plants. Concerning their effect on the nitrate content of soils, the upper three feet, where weeds were permitted to grow, contained 81.6 pounds of nitrates, while a comparable area with a three-inch mulch contained 413.3 pounds of nitrates to the acre (64).

Practically every State has laws regulating the sale of crop seeds and limiting the sale of those containing mixtures of certain undesirable weed seeds. Aside from the reduced yields of the crop variety as a result of weed competition, the presence of the weed seeds greatly lowers the market value of the crop seed and thus imposes a double tax on the farmer. Rather (307) discusses some of the significant relationships between weeds and the marketing of farm seeds.

Plants commonly classed as weeds are not always harmful, however. They may do much good in providing cover to prevent erosion and through their growth may increase the available fertility of soil; tobacco, for instance, following certain species of weeds, is superior to that produced on bare fallow (237).

CHARACTERISTICS AND FOOD RESERVES OF WEEDY PLANTS

Before one can hope to effectively control undesirable weed plants, it is important that he understand the fundamental characteristics pertinent to each species. A very desirable plant under certain conditions may be undesirable if it becomes so well established that it effectively competes with desired species. Sweet clover persisting in a cultivated corn field may prove highly undesirable, and to all purposes it is a weed under these conditions. Numerous investigators have considered the physiology and anatomy of various weed plants with a view to learning principles which might direct their modes of attack in securing most efficient control. It seems desirable to review some of the fundamental work before turning to specific control measures.

Cole and Holch (71) discuss the root systems of 21 weeds in southeastern Nebraska. Kiltz (206) describes the root systems of 10 perennial weeds. Hardy (160) discusses the root systems of several weeds in relation to tillage. There is also a very complete study of the root development of weeds and crops in competition, in which Hannchen barley competed more successfully with wild oats and wild mustard than did Marquis wheat, due to the more rapid seminal root development of the barley (287–289). Norris (269) reports on an ecological study of weeds in eastern Nebraska. An excellent treatment of the anatomical development of *Lepidium Draba* (L.) is reported by Simonds (337). Kennedy and Crafts (200) discuss the application of physiological methods to weed control. In later work (201) the same authors describe the anatomy of field bindweed. Kirk and Pavylchenko (209) report that land infested with wild oats may produce new plants by vegetative regrowth following tillage shortly after the seedlings emerge. The vegetative reproduction depends upon the moisture of the soil and the degree of packing.

An important function of the thickened roots and rhizomes of perennial weeds is to store reserve food materials. While some of

this reserve material may be used by the plant during the dormant period, by far most of it remains there until the critical period in spring when the plant must produce considerable new growth of leaves and stems before it can again synthesize all the food materials it needs. A portion of the reserve material is used to carry on the normal respiratory processes of the plant. Plants endowed with the capacity to store great reserves are equipped to survive under unfavorable environmental conditions. It is only logical to expect that these plants are very likely to be extremely persistent and thus frequently to fall in the category of weeds.

In a consideration of the reserves of a weed, one is concerned with the anatomy of the plant. In most cases, the root characteristics are of special significance, since the roots serve as the primary storage organs and thus play an important part in the ability of many species to persist as weeds. Field bindweed roots may penetrate the soil to a depth of 20 feet (21), and may yield a maximum acre production of 7,200 pounds (23). Total sugar and polysaccharide reserves in the roots were less than 600 pounds. The authors believe that the persistence of bindweed under fallow is due to the small quantity of reserves necessary for regeneration of new growth and to slow rate of removal of reserves from the roots at lower depths. Application of sodium chlorate resulted in an immediate drop in root reserves, suggesting a direct effect of the chemicals upon the respiratory rates or other processes in treated roots. Both fallow and chlorate treatments resulted in rapid depletion of polysaccharide reserves in the roots in the upper foot of soil.

In studies of bindweed reserves, total sugars reached a maximum of about 7% late in October with a minimum value in May (28, 29). Starches increased gradually, reaching a maximum in August or September, followed by a sharp decline coincident with the rapid increase in sugar percentage. Cultivation at two week intervals held the total sugar and starch content each to about 1%. Fall applications of sodium chlorate were more effective than early applications in reducing root reserves and controlling the weed.

In field bindweed studies in Kansas on the readily available carbohydrates at different dates of sampling, all carbohydrate fractions except the reducing sugar were lowest between April 15 and May 15. Total sugars were highest in the lateral roots and the first foot portion of the two types of vertical roots the first of November. In

other root portions there was a tendency for the high point to be on or before July 15 with a maximum later in the season but prior to November 1 (128).

In very comprehensive trials in the control of field bindweed in western Kansas, the percentage of readily available carbohydrate reserves declined rapidly with continued cultivation until about July 1, after which it remained about the same. The total amount of living roots decreased slowly at first but more rapidly after July 1, and this decrease continued until all plants were dead. At the end of the season approximately 95% of the roots in the surface 18 inches of soil had died, with complete eradication usually by the middle of the second year. Following a single cultivation of untreated bindweed having a high level of root reserves, the percentage of carbohydrates decreased slowly until about four days after first emergence of the bindweed. After this, the decrease was more rapid and continued for a period of from 8 to 20 days after first emergence with an average of about 16 days. Following 16 days, as a rule, there was a rapid increase in reserves as the plant began building up a surplus. This work proves that bindweed may be eradicated just as quickly and with fewer cultivations by cultivating every two to three weeks as by continuous tillage (377). Results at Lamberton, Minnesota, were similar (402). In fact, at Lamberton continuous cultivation requires a somewhat longer period to secure complete eradication than where intervals of two weeks after emergence are followed.

Field bindweed appears to maintain itself when the moisture content of the upper two feet of the soil is below the wilting coefficient (20), and to produce an abundance of seed in seasons of high temperature and low rainfall (56).

Rapid movement of reserve materials out of the storage roots early in the season results in a reduction in dry weight parts at the time, followed by an increase in dry weight as the reserves are again stored in these organs. In data bearing this out, the underground storage organs of quack grass and Austrian field cress reached their maximum weight earlier in the season than did leafy spurge, sow thistle or Canada thistle. The author (11) attributed this to the greater leaf area of the quack grass and cress formed the previous season, which lived over winter and was ready to synthesize food as soon as growth started in the spring. He found sharp declines

from late April through the first part of May in the percentages of total sugars and total readily available carbohydrates in the storage roots of each of the weeds with the exception of quack grass. The total readily available carbohydrates in the storage roots of leafy spurge and Austrian field cress were lowest for the season by the middle of May, at which time the plants were beginning to flower. Rapid storage of these materials occurred for a time and continued at more moderate rates to the end of the growing season.

Sow and Canada thistle, two weeds which start growth later in spring, declined rapidly at first in total readily available carbohydrates and continued at more moderate rates to the first part of July when the plants were in flower. Reserves accumulated from that time to the end of the season.

Rhizomes of quack grass were lower in both percentage and pounds per acre of total readily available carbohydrates in April at the time the first determinations were made than on any later sampling date, indicating depletion of reserves as a result of the winter season.

The readily available carbohydrates in the underground storage organs of each of the weeds except quack grass were low in relation to the total reserve carbohydrates in the middle of July.

Marked decreases in the percentages of true starch and increases in sugars in the underground storage organs of sow and Canada thistles and leafy spurge accompanied the lowering of temperatures in the fall. It appeared that similar changes did not occur in the underground storage organs of Austrian field cress and quack grass.

There were rapid declines in total organic nitrogen in the underground storage organs of sow thistle and Austrian field cress and less marked declines in those of Canada thistle, leafy spurge and quack grass during the early part of the season. These declines continued at a reduced rate until August, after which increases occurred.

Arny found the common form of storage sugar in underground parts of plants was the non-reducing sucrose or cane sugar. This is changed to simpler reducing forms before being utilized by plants. Thus the presence of reducing forms of sugar in any amount usually indicates activity in the translocation of reserves.

In sow thistle the percentage of reducing sugars increased during late April and the first part of May. Austrian field cress, Canada

thistle and leafy spurge decreases were noted during the first part of the sampling period.

As the temperatures lowered in the fall, leafy spurge, sow thistle and Canada thistle showed a change in the carbohydrate reserves from starch to sugar. In neither quack grass nor Austrian field cress was there any indication of marked change from starch to sugar with the lower temperatures of fall.

The storage organs of sow and Canada thistle contained a lower percentage of hemicelluloses than the other three weeds. Hemicellulose reserves are relatively more stable than the other carbohydrate reserves and hence are used as the supply of the more labile materials is reduced. An increase of hemicelluloses during the early part and lowering during the latter part of the sampling period was the trend. In general, this was the opposite of what occurred for the more readily available carbohydrates.

With leafy spurge, Austrian field cress, sow thistle and Canada thistle the total and readily available carbohydrates reached low points at the same time the plants began to flower. Except in field cress, the total organic nitrogen was lower at this period. It would appear then that this should be a good time to begin eradication operations.

Under Minnesota conditions the weather is usually more favorable for eradication by tillage during July and August than either earlier or later. Considering all points, the first part of July appears to be a good time to initiate eradication of quack grass.

Cutting the tops of weeds near the soil surface at beginning bloom compels the plant to build a new set of aerial organs which involves additional drain on the reserves in the underground parts and has the further advantage of preventing seed formation.

Under Missouri conditions the weight of reserve storage organs of timothy and their nitrogen content was lowest in early spring and increased rapidly to early bloom and then less rapidly to maturity (382).

The percentage of total carbohydrate reserves in underground parts of Canada thistle was lowest during the latter part of June when the plants began to flower (315), and in winter studies of the activity of the roots and its relation to control methods, the author noted the development of buds upon the roots and of new horizontal roots upon the old storage organs (316). Ohio investigations

(392) on reserves in the roots of Canada thistle, calculated on the basis of green weights, seem to substantiate these findings. The data show that the nitrogen content of the roots tends to decrease to about July and then to increase again. Clipping the plants resulted in lowered food reserves in the roots.

Root reserves of white weed showed no material change in carbohydrate percentages until 14 to 16 days after cultivation, and biweekly cultivations were equally effective as weekly cultivations (30).

Sturkie (367) reports that cutting Johnson grass for hay in immature stages weakened the plants. Where he cut the plants but once a year when the plants were relatively mature and the seeds in the milk stage, there was a 40% greater development of rootstocks than where the plants were harvested continuously in the immature stages. The plants harvested when mature were much more vigorous and produced much more vegetation the following year.

Dexter (109) studied the winter hardiness of weeds as affected by fertilizers. He found that Canada thistle, downy brome grass and field bindweed became more hardy with the coming of cool weather. If photosynthesis were prevented in the fall, quack grass receiving nitrogenous fertilizer failed to harden while the unfertilized rhizomes did harden. Naturally the unhardened plants were more subject to winter injury. Later investigations (195) report that applications of nitrogen stimulated a vegetative response in more top growth. Continual removal of this top growth caused the plant to draw upon its organic reserves, resulting in carbohydrate starvation and death of most plants in about 24 weeks. Frequent defoliation prevented quack grass rhizome formation and destroyed the plants, even though they were fertilized (108), and rhizomes from plants fertilized with ammonium sulphate were more subject to drouth injury than rhizomes from untreated plants (110).

Dexter (111), studying the reserves of quack grass, recommends thorough tillage in the early part of the season to secure drying out and most effective destruction.

The reserves of several pasture weeds have been found to be lowest just before bud formation (146). This has an important relationship to the best time to destroy the weeds. In buckbrush, sumac, vervain and iron weed of Kansas, there also was a reduction of root reserves from spring to the time of budding or flowering,

and then an increase to the close of the season (3). Cutting treatments begun when the reserves were low were more effective than when begun at other times.

CONTROLLING WEEDS

There are two general methods of approaching the weed problem—one is to work for outright eradication of the weed and the other is to keep it under such control that its harmfulness is greatly reduced. With certain very bad weeds the former method is to be desired and should be practiced wherever possible. In general, most weeds such as the more common annual species are held under control without actual eradication. In fact, their complete eradication would be so costly in most cases that it would not be economical to carry out the necessary practices. One prominent agriculturist has defined weed control as "good farming", meaning that a proper system of farming with operations well performed results in weed control.

Many general books have been written on the subject of weeds. Georgia (137) has prepared an excellent book which gives good illustrations as well as descriptions of plants and methods of control. While the book is somewhat old it is extremely useful. No weed library would be complete without Gray's Manual of Botany (149) and the splendid publications by Britton and Brown (52).

Robbins, Crafts and Raynor (313) and Muenscher (260) have published up-to-date books on weeds. Other general weed books have been written by Pammel (281), Pammel and King (283), Korsmo (214, 216) and Spencer (353).

A well-illustrated bulletin treats of representative Missouri weeds (115). Larson *et al.* (220, 221, 222) describe and illustrate several of the more common weeds. Cox (81), in a government bulletin, discusses weeds in general. Darlington *et al.* (102) describe 94 Michigan weeds and give methods of control.

Wilson and Larson (401) published a manual which deals with identification of the more common weeds. It is illustrated with numerous drawings which emphasize the characteristics making identification possible. In addition, the book treats of crop judging with emphasis on the significance of weed seed mixtures.

Muenscher (258) lists the weeds of New York by families. Gates (136) gives a short but concise treatment of methods of con-

trolling various types, and a comprehensive discussion of the more important weedy plants of Kansas. Brenchley (46) treats of weeds in England. Robbins (311) gives methods of control used in central Europe. Several publications (25, 40, 44, 45, 60, 69, 78, 96, 99, 106, 113, 121, 151, 155, 194, 203, 207, 212, 215, 229, 246, 256, 275, 276, 277, 284, 285, 296, 306, 323, 340, 358, 364, 373, 383 and 400) deal with weeds in various other areas.

Control of noxious plants usually requires the use of one of two methods: cultural methods or chemical eradicants. Either may be used alone or both in combination. Cultural methods are considered to include rotation methods, growing of so-called smother crops, or any system of farm management which may aid in weed control. Use of chemicals involves application of certain toxic compounds capable of destroying the undesirable plants. Man has employed tillage methods for centuries. Extensive use of chemical eradicants has been confined to recent years. The proper evaluation of weed trials is important. Lynes (238) has shown how modern statistical methods may be applied to weed research.

Weed control is no longer a simple matter of maintaining good crop rotation or doing a thorough job of preparing a seed bed. With the great spread of especially vicious weedy plants, in many cases control revolves around specialized programs planned for particular species. For this reason it is logical that the published research be considered under more specific headings.

It is not practical to discuss the research with all weeds. It seems desirable rather to select certain phases of control work and to present the results secured from a number of investigations. The principles apply to species possessing similar characteristics.

Tillage Methods

As early as 1886, Sturtevant (370) showed that where weeds were permitted to grow, corn yielded 18.1 bushels per acre, while where the weeds were pulled and the land received no cultivation, the yield was 70.5 bushels. Elsewhere a six-year average yield of corn was 7.0 bushels per acre where weeds were allowed to grow, 53.3 bushels where the weeds were scraped with a hoe (403). Similar results have been reported by other authors (59, 67, 177, 204, 228, 373).

Pereira (291) reports on a series of cultivation tests with several row crops. He summarizes a number of British and American

experiments on tillage which agree with his work in support of the theory that the principal purpose of cultivation is to control weeds.

In weed control, tillage may vary from the simple act of hand pulling the undesirable plants to the use of specialized machinery constructed expressly for destruction of weeds. The duckfoot cultivator is an example of such a specialized implement.

Hardy (161) does not favor deep plowing, as he believes that such a procedure merely postpones the difficulties. He recommends that annual weeds be given a light disking to cover the seeds in the fall. The following spring when the plants are about five inches tall they may be destroyed by shallow tillage. He believes the land should not be cultivated deeper than four inches in the control of annual weeds. The shallow tillage may be repeated five or six times during the summer season.

Shedd, Collins and Davidson (335), discussing weed control from the viewpoint of the engineer, state that the principal purpose of corn cultivation is to control weeds. The spring tooth weeder and rotary hoe were effective in destroying weed seedlings when the soil surface was lightly crusted by moderate rainfall. They did not prove as effective if the soil crust was heavy or was loose and dry. For a program of tillage they recommend six sweeps per row and rotary hoe shields for small corn. For the second cultivation a pair of disk hillers was used to throw the soil into the row. For the last cultivation similar treatment was followed, using two pairs of sweeps per row. The speed of the tractor cultivator should be between two and a half and four miles per hour.

Dieffenbach (112) describes weed machinery used in Utah and Idaho. Robbins suggests (312) control in orchards with both tillage and herbicides. Smith (345) discusses machinery suited to the control of field bindweed by tillage. Bioletti (34) at Davis, California, found that ordinary tillage would not control bindweed. By cutting the roots three inches below the surface every five days he was able to secure close to 100% kill in one season. Barnum (27), also working at Davis, California, was unable to control bindweed when the tillage intervals were two weeks. He recommended cultivating four to six inches deep about every five days. He reported that hogs may destroy bindweed by eating its roots. Wilson *et al.* (402) were able to greatly reduce the cost of eradicating field bindweed by tillage by extending the intervals be-

tween cultivations with a power operated duckfoot cultivator to two weeks after emergence of the new growth. Srb *et al.* (354), using a duckfoot cultivator and tractor, found that field bindweed in Nebraska could be eradicated at a cost of approximately $10.00 per acre.

Since special weed tools are costly and difficult to obtain, considerable work has been done to develop homemade implements. There are publications giving information on the construction of such machines (397, 402, 407). The Kansas State Board of Agriculture (8), in a discussion of field bindweed eradication, presents the results of Kansas control methods, as obtained on the farms of the State. Included are illustrations of methods of developing homemade implements.

Timmons (376) states that clean cultivation is the most dependable of all eradication methods. Best results were obtained when the bindweed was permitted to grow several days above ground after each cultivation with the duckfoot. Clean tillage costs ranged from $5 to $10 per acre. Frazier (127) recommends 14-day intervals between cultivations.

In southwestern Minnesota a thorough job of tillage spread over two years to eradicate field bindweed cost $12.70 per acre. This cost covered the period from 1936 to 1941 and included plowing once each season at a depth of five inches and ten cultivations each season with a duckfoot cultivator (402).

In other detailed experiments it required more than 70 cultivations over 2½ years to secure 100% kill of field bindweed on a 32-acre field that was cultivated as soon as the plants emerged (346).

General papers on bindweed control include (32, 122, 199, 205, 328, 400).

Canada thistle (*Cirsium arvense* (L.) Scop.) may be spread vegetatively by cuttings of horizontal or vertical roots and of upright subterranean stem shoots bearing nodes. Portions of root or of stem ⅛ to ¼ inch in diameter and ½ inch long produced new plants under favorable conditions (170).

Porter (295) advises plowing deep in July or August followed by fallow once a week until late fall to eradicate Canada thistle. The operations should be repeated the next year. A smother crop as millet, Sudan grass or sorghum may be planted in June. If the

work is done properly, eradication should be complete within three years. Tillage on large areas and sodium chlorate on smaller infestations are also recommended as means of eradicating Canada thistle (399).

Quack grass (*Agropyron repens* (L.) Beauv.) is best adapted to the cooler sections of the United States, being well suited to the upper Mississippi Valley. Not infrequently perennial sow thistle (*Sonchus arvensis* L.) is found growing on the same farm, as the regions of adaptation for the two weeds are similar. Quack grass is more widely distributed than is sow thistle. Both species possess underground root structures which make it difficult to control them with ordinary tillage.

Arny (9) states that thorough tillage is necessary to eradicate quack grass. He recommended plowing in July, three to four inches deep; replowing not later than August 15, five to six inches deep; and again in November, six to seven inches deep. The disk was used between plowings to keep the quack grass from showing green above ground. Other authors give cultural methods for control of quack grass (384), recommend deep plowing (25–27 cm.) to destroy it (334), discuss the use of shallow tillage in the control of perennial weeds (290), outline the methods for controlling quack grass in South Dakota (189) and give information pertinent to the entire country (202).

Stoa *et al.* (365) reported spring and fall tillage as less effective than summer tillage in eradicating quack grass. Working at the Crookston Station, Dunham (117) recommends early spring and late fall plowing, with a thorough bare fallow to secure eradication of perennial sow thistle. In unpublished work in Minnesota, Arny was able to obtain 99.6% eradication of leafy spurge (*Euphorbia Esula* L.) in one year at a cost of about $12 per acre. Two years of fallow at a cost of $24.00 per acre were required to secure complete eradication.

Cultivating the land 30 times each year for two years destroyed leafy spurge, but cultivating corn four or five times in a season failed to eradicate it (18, 19). The same author describes the characteristics, habits and distribution of leafy spurge in Iowa. In another discussion of the characteristics and control of leafy spurge, sodium chlorate was best for small areas, and cultivation best on large sections (156, 157, 158). Tinline (381) gives methods of eradicating leafy spurge in Canada.

In studies of perennial peppergrass (*Lepidium Draba* L.) two seasons of thorough tillage followed by two years of check-rowed crops was the most economical and practical method of eradicating the weeds (187). Other workers outline methods of tillage for the control of white top (171, 172, 250, 319).

A year of cultivation of irrigated land infested with *Lepidium Draba,* followed by a very heavy seeding of grasses, clovers and alfalfa, resulted in crowding out of the weeds (125). Andrew (5), quoting Ewart, recommends summer fallow started with deep plowing, followed by a root crop as an effective means of controlling this weed.

One of the worst weeds of the South is Johnson grass (*Sorghum halepense* (L.) Pers.). It is to the South very much the same as quack grass is to the North. Deep plowing in June, July or August with removal and destruction of all roots and tops from each plowed furrow was effective. The land is plowed again in late November. The following year the process is repeated until eradication is complete (178).

Johnson grass is very bad in southern Indiana (226). Control was secured by plowing winter wheat land as soon as the crop was harvested with a disk or cultivator being used to keep the land black until fall. Wheat was seeded and the operations repeated a second year. Methods of controlling quack grass in New Mexico have been outlined in detail (278).

Nut grass was eradicated by plowing at intervals of three weeks during two successive growing seasons (348, 349). Areas likely to remain wet for long periods do not respond to cultivation. Exposure of nut-grass tubers to four days direct sunlight resulted in their destruction (347). Fromm (132) reported that simultaneous tillage and application of a 2 N thiocyanate solution proved equally as effective and cheaper in the control of nut grass than methods of tillage. One liter of 2 N calcium thiocyanate per square meter reduced the stand to 1% or less in 90 days.

Wild garlic does much damage in areas where adapted, and in addition to competing with crop plants, it lowers their market quality. General control is discussed by Skiver (343). Use of orchard heating oil for its destruction offers promise (13).

Brush-like plants such as brambles may be classed as weeds, since they interfere with the growth of desired plants. Comprehensive

methods of control in pastures are available (43, 100). Effective control of brambles was obtained when sodium chlorate was applied about the time of fruiting (77). Renovation of pastures and its effect upon the control of weeds is closely related to brush control (134).

Mowing brush in July was the best time to subdue undersirable species (53). The most effective date of cutting was closely correlated with the time when the roots of the bushes contained the least amount of organic reserves (4).

Wild ferns are a serious menace in some sections. Through proper management they may be controlled in pasture lands of eastern United States (80).

While there are many other weedy plants of importance, all may be controlled by following the basic principles of clean cultivation. Prevention of growth ultimately exhausts the reserves of even the most vigorous weedy plant and may lead to its final destruction. The problem before the farmer is to utilize the best and most economical methods of control. In many cases these involve tillage alone, in others the use of chemicals, and in some instances a combination of tillage and chemical eradicants.

Brenchley and Warrington (48, 49, 50, 51) give a very complete report of the influence of crop, soil and methods of cultivation upon the relative abundance of viable seeds. In Sweden, harrowing to control weeds gave an average increase in grain yields of 8% and a second harrowing gave an additional increase of 3% (116).

Special Methods

A few special methods of control have been developed. Use of a flame, for instance, has been recommended as a successful and practical method of eradication (79), and the effects of ensiling are not to be overlooked (409). Under the latter category, seeds of rough pigweed, yellow foxtail, Johnson grass, smartweed, sunflower and cocklebur have been found to be destroyed by storage in sorghum and corn silage, while seeds of field bindweed, velvet weed, annual morning glory, giant ragweed and barn-yard grass were resistant (409). Of 29 varieties stored in alfalfa grass silage for periods of one week to five months, most of the seeds lost their viability but a few retained it even after storage. The weeds whose seeds were most resistant were lespedeza, field bindweed and dragonhead

mint (405). Tildesley (375) destroyed the viability of 19 species by storage in silage juices which showed 1.5 to 2.0% of organic acids.

Any method of weed control must consider the animal as an important means of distribution, as it has been shown that not all weed seeds lose their viability in passing through the digestive tracts of farm animals (17, 211, 274). The proper composting of manure from animals consuming weed seeds is a recommended method of weed control. At the Rothamsted Station the cumulative effect of long-continued manuring appeared to be of secondary importance in relation to weed flora except in certain instances of serious deficiency, and the manures used did not seriously increase the weed population (388). One month of storage in cow manure and horse manure destroyed all seeds with the exception of velvet weed, bindweed, sweet clover and peppergrass (162). Field bindweed retained its viability after storage for four months in piles of chicken manure (366). Composting to control weeds relates to the entire subject of weed seeds in relation to their environment, and the effect of temperature variations on seed germination in the soil is important (1, 2, 33, 389). It must be remembered that not all composting is done well, and many weed seeds escape destruction, even though an effort is made to eliminate them by composting.

At Fort Hays, Kansas, an average of 20 tillage operations the first year killed 85% to 99% of the field bindweed plants (65). Other investigators proved that bindweed could be destroyed by shallow tillage only if the cultivations were made at frequent intervals (360). Control of bindweed in Scotland was effected by deep plowing and cultivation followed by harrowing to drag the roots into heaps (350). In Missouri the removal of trash, followed by 8-inch plowing about May 1 and then clean cultivation with a duckfoot cultivator every week to ten days until October 1 to 15, is a recommended practice (124). On land subject to erosion, rye may follow the clean tillage. Cultivation each eight to ten days was effective in eradicating bindweed, while tillage at intervals of two weeks with wheat seeded in the fall reduced the number of cultivations and permitted the growing of a cash crop (138). Other investigators have obtained comparable results (126, 205, 408). Control of field bindweed by repeated and gradually deepened plowing has shown promise (210), while Smith (345)

has devised special weeder machines to expedite the fallowing of infested land.

Cropping Methods

As has been shown, any system of tillage involves added expense and constitutes a severe tax upon the farm. If it is possible to grow crops during eradication, one may greatly reduce his costs. It is well known that most plants, grown together, are in direct competition with one another. This competition may seriously affect crop yields. In western Kansas grain and forage yields of nine different crops were reduced from 20% to nearly 90% by field bindweed competition (377). Tall growing, broad-leaved plants exclude light from the shorter or slower growing plants. Some workers refer to certain types of crops as smother crops. No plant actually smothers another; a so-called smother crop is one that merely screens the sunlight from the lower plants.

Pavlychenko and Harrington (288) did an excellent piece of research on the competitive efficiency of weeds and cereal crops in showing that competitive efficiency was related to the ability of the plant to develop rapidly after germination. They write: "In competition supremacy may be attained by the species or variety which is able, by virtue of greater physiological activity and morphological adaptability, to utilize the environment more efficiently. Rate of growth may be the best manifestation of such efficiency. Readiness and uniformity of germination, if characteristic of a species or variety, may be of considerable importance. Similarly, facilities for the absorption of water and nutrients and for the assimilation of carbon dioxide may be important factors. These facilities involve all of the plant, including the underground portion". Similar work in Germany expressed viewpoints more or less in agreement (218, 219). To discover desirable types of plants capable of suppressing the undesirables is one of the objectives of weed research.

Research at the Lamberton, Minnesota, Weed Station has shown that sudan grass, millet, sorghum, soybean, alfalfa and brome grass are excellent competitors of field bindweed, provided a period of cultivation precedes seeding of the crop (355). Light values under different crops were determined with a Weston photo-electric cell, and correlations were found between the lower values and field competition, as evidenced by reduced vigor of the bindweed plants.

While both sunflowers and hemp have been credited with being good weed competitors, neither proved satisfactory in these trials, as it appeared that both species lost their lower leaves rapidly, thus permitting light infiltration.

Blackman and Templeman (38) concluded that in a year of normal rainfall competition between the crop and the weed is principally for nitrogen and light.

Using a photo-electric cell, a German worker studied the effect of various crops as shade plants to compete with weeds, and found rye was a better shade plant than wheat because the rye shade increased more rapidly (304). In work at the Lamberton Weed Farm in Minnesota it has been observed that winter wheat was more effective in competition with field bindweed than rye, since it maintained its shade later in the season. This is true only where winter wheat is well adapted.

Field bindweed was checked through a combination of tillage and the growing of rye (126). Other workers found alfalfa to be effective in checking the growth of bindweed (21, 328). Russian sunflowers reduced the stand about 90% (360).

Studies in Minnesota by Arny (10) have shown that Canada thistle may be eliminated through the growing of alfalfa. Thorough seedbed preparation is essential to permit establishment of the alfalfa crop. Following this, frequent cutting of the alfalfa does not permit the thistles to recover, and they may be eradicated within two to three years. Other workers have secured similar results (107). When the alfalfa was cut three times the year after seeding, no thistles were found the following or third year, with a good stand of alfalfa averaging 4.5 tons of hay per acre.

In Saskatchewan, crested wheat grass in three seasons completely smothered thick stands of perennial sow thistle and toad flax (286). In four seasons it eliminated Canada thistle and effectively controlled quack grass, leafy spurge, poverty weed, field bindweed and hoary cress. In Minnesota (402) it has been possible to control field bindweed by growing alfalfa and cultivating the latter until the middle of summer. A season of tillage with a duckfoot cultivator followed by rye or winter wheat where adapted has also proved successful in eliminating bindweed under Minnesota conditions, and many farmers have used the rye or winter wheat program in ridding their farms of this weed.

Use of heavier rates of seeding and fertilizers drilled with the seed to increase competition have checked annual weeds in cereals (142, 143). Nitrogenous fertilizers were used to increase competition between crop plants and vetch (303). There is some evidence to indicate a direct competitive effect of the growing plant. In a series of pot studies, rye or winter wheat grown with the weeds *Anthemis arvensis* L. and *Matricaria inodora* L. under certain conditions inhibited germination and development of the weeds (305). Rye exerted a more depressing effect than wheat, believed to be due in part to an antagonistic factor.

Grazing animals may be considered in relation to cropping practices. If livestock can be grazed effectively one may eliminate the weedy plants and at the same time gain a fair return from the forage provided. Various claims have been made regarding different classes of livestock used in this way. Sheep probably have proved more generally effective because of their willingness to eat herbage rejected by most animals and their inclination to graze closely, thus preventing plant recovery. At the Lamberton, Minnesota, Weed Station a period of cultivation followed by rye or winter wheat grazed heavily in the spring until the crop was consumed eliminated field bindweed within two to three seasons. Following death of the pastured grain, the land is plowed and either of two plans may be followed. The area may be cultivated until fall when fall grain is again seeded or sudan grass may be planted as soon as a good seedbed can be prepared. The latter method reduces labor costs and provides further pasturage.

Hogs and sheep were ineffective in controlling bindweed in Nebraska (204), while in Utah about 90% control of bindweed was secured by hogs in pasture (361). In Iowa trials neither leafy spurge nor field bindweed was controlled with sheep or hogs (19). Workers at the North Dakota Agricultural Experiment Station were successful in cleaning areas of leafy spurge with sheep (175). Likewise, the Minnesota Agricultural Experiment Station has found that sheep may be used to good advantage in destroying leafy spurge. Muenscher (255) also advises use of sheep in controlling leafy spurge under New York conditions.

Chemicals

In 1896 a French grape grower by the name of Bonnet, while applying Bordeaux mixture to his vines, noticed that the leaves on

mustard plants in his vineyard turned black when the spray solution fell upon them (41). The news of this effect spread, and soon experiments in weed control with chemicals were numerous. Another early French worker reported the use of iron sulphate and copper sulphate spray to control dodder plants in alfalfa (179), and in 1896 Bolley experimented with copper sulphate as a weed eradicant and was one of the early workers to give methods of using spray equipment (39).

Some spray materials are effective by destroying plant tissue upon coming in contact with it. In general, these sprays are used on annual plants which cannot recover after destruction of their vegetative parts. Many of the sprays which kill by contact are applied in very dilute solutions and do not render the soil sterile. In some cases they are selective in that certain plants are destroyed while others receive little or no injury.

Sulphuric Acid and the Sulphates. For many years sulphuric acid has been used as a selective spray in control of such annual weeds as mustard. In 1911 6% to 10% solutions of it at the rate of 107 gallons per acre were used in grain fields (297), and later work by the same investigator gave other results (298, 299, 300, 301, 302). Korsmo (212) found that a 3.5% to 4% solution would destroy those annual weeds to which the acid would adhere, and he secured increased yields of from 561 to 603 pounds of mixed grains per acre. Other work at the same station also gave good results and showed that atmospheric conditions had little influence upon the effectiveness of the acid when used to destroy mustard in small grains. An hour usually was sufficient for permanent destruction except during cold, wet weather (14).

In California, workers recommend application of a 10% concentration by weight of 66° Baumé commercial sulphuric acid applied at the rate of 130 gallons per acre (129). At an application cost of $3.00 per acre, barley fields infested with mustard showed an increased yield of 50%. Sulphuric acid treatment has reduced lodging of barley (24), and successful use of it has been reported in Arizona (57). Thornton and Durrell (374) state that a 5% solution will kill the majority of weeds encountered on the farm, including dodder, and they believe that the effectiveness of the acid is favored by low humidity and high temperature. From 50 to 200 gallons were required per acre when the weed growth was from four to six inches high.

Blackman and Templeman (37), who secured an average of 90% control of *Brassica arvensis* (L.) Ktze., using a 9.2% concentration of sulphuric acid, noted some cases of damage to the crop. An anonymous worker (7) recommends control of charlock in cereals with a 100 to 150 gallon per acre application of a 7% to 10% solution.

In western Canada, sulphuric acid and copper sulphate have been recommended for economical control of wild mustard in wheat (140, 141). Stinkweed or French weed was controlled by sulphuric acid only. Applications of 30 pounds of copper sulphate (3% sol.) and 60 pounds of sulphuric acid (6% sol.) per acre gave a reduction of 87% to 90% in amount of weed seeds in the crop, and the yields of harvested grain in the treated plots were, respectively, 5.3 and 2.7 bushels per acre higher than in the untreated weed plots. Sulphuric acid controlled common wild mustard, Indian mustard, wild radish, stinkweed, false flax, tumbling mustard and wild buckwheat growing in wheat. Under the conditions of the experiment, Canada thistle, hare's ear mustard, ball mustard, cow cockle, lambsquarters, Russian pigweed and grasses were not controlled. In resistance to sulphuric acid the cereals ranked as follows: resistant—wheat, oats; intermediate—barley, spring rye; susceptible—corn.

Vigor used iron sulphate to control mustard in grain fields (385), and St. John's wort was destroyed with a 5% solution of sulphuric acid (308). Sulphuric acid methods in France are of interest (342). Sourdille (352), for instance, controlled weeds in grain fields with it and ammonium sulphate, and similar results are reported for Italian trials (249).

Suitable equipment for applying sulphuric acid is essential (24, 130, 131). Because of the corrosive nature of the acid it is necessary to use certain resistant materials such as brass, bronze of low zinc content, rubber and special grades of steel or iron made from an alloy of copper, silicon and manganese. It is interesting that while concentrated sulphuric acid may be handled in steel or wrought iron, the diluted acid will corrode both.

Sodium dinitro-orthocresylate. Recently there has been introduced a new type of selective herbicide, an organic dye, sodium dinitro-orthocresylate, sold under the trade name of Sinox. Most experiments have indicated its usefulness in the control of such broad-leaved weeds as mustards. Since the grasses and flax are

tolerant of Sinox it may effectively destroy the undesirable mustards and leave the crop uninjured. Sinox has the added advantage of being non-corrosive and non-poisonous in the quantities used. To secure the most effective action, the spray solution should receive an acid salt, such as ammonium sulphate or ammonium bisulphate, to increase the hydrogen-ion concentration of the spray and, in turn, to increase the concentration of the dinitro-orthocresylic acid in the solution (139). Westgate and Raynor (396) rate activated Sinox as equal in effectiveness to any other selective herbicide. They found it to be effective on vetch, corn cockle, sunflower, black nightshade, mustard and wild radish, all weeds that infest grain fields in California. There appears to be considerable advantage in yield and quality of flax produced in plots sprayed with Sinox as compared with untreated areas (176). Favorable results with Sinox were secured also in Oregon where it is recommended as a selective weed killer in wheat, barley, flax, peas and certain grass seed crops, and proves especially effective in the control of mustard growing in flax (164). Similar results have been secured in Wisconsin and Minnesota (332, 402).

Arsenicals. Arsenical compounds have been effectively employed by numerous investigators. In 1892 sodium arsenite was used in Africa to kill prickly pears (242), and both annual and perennial weeds of Hawaiian rubber plantations have since been controlled by it (244). The latter investigator considered the possibility of damage to the soil as a result of arsenic accumulation from the treatments on undisturbed land that had received three sprayings of five pounds of arsenic per acre per year for five years. Under the very heavy rainfall of the area (200 inches per year) the first four inches of the soil contained 0.009% of arsenic and no arsenic was found below this level.

In Minnesota sodium arsenite applied to quack grass at the rate of four pounds dissolved in ten gallons of water per square rod gave a 90% kill. Heavier applications effectively destroyed long-lived perennials but made the soil sterile for several years. The results of these investigations are unpublished.

Crafts and his co-workers in California have done much work on the use of chemicals in weed control. One must remember that soil and climatic conditions in one part of the country may differ widely from those in another section. In California, for example,

sodium arsenite has been successful and is recommended for use under certain conditions. Extensive studies have been made in California using a combination of arsenic trioxide and sulphuric acid, the sulphuric acid proving useful as a penetrating agent (82, 83, 85, 87, 89). Four parts by weight of As_2O_3 and one part by weight of NaOH were mixed dry, and three parts by weight of water added. The mixture was then thoroughly stirred until the salts were dissolved, and the thoroughly mixed combination next received five parts by weight of concentrated sulphuric acid. The resulting mixture, diluted with 100 parts by weight of water when used, was sprayed under 100 pounds pressure at the rate of 500 gallons per acre. This treatment proved effective in California but is ineffective in more humid areas. The spray exerts no permanent injurious effect upon the soil. Later studies with a group of 80 California soils corroborate the earlier results of arsenical effectiveness (95). In the fog belt of California four pounds of arsenic trioxide were dissolved in 100 gallons of water, and applications of 300 gallons of spray per acre in October successfully eradicated field bindweed (150).

In Australia one application of 120 gallons per acre of a 6% solution of arsenic pentoxide gave up to 95% eradication of *Lepidium Draba* L. (251, 252, 253). Most effective results were secured when treatment was made after a period of dry hot weather. Some investigators believe pentoxide to be the most satisfactory form of arsenic for herbicidal purposes (66, 344).

Crafts (85), working with four different California soils in the greenhouse, found trivalent arsenic the most feasible chemical for soil sterilization, based on cost. Further greenhouse investigations showed a mixture of white arsenic and sodium chlorate to be useful in soil sterilization (94). In dry areas considerable use is made of the arsenicals to sterilize soils around fence lines, irrigation ditches, *etc.* (97). Because of their very poisonous characteristics, extreme care in use is important (89).

Other investigations of arsenical herbicides include those of McDonald (242) and Morgan (250), and a study which gives evidence that the toxicity of arsenicals is inversely related to their fixation by the soil (320). Little or no effect on soil productivity of several Cotton Belt soils was noted if applications of calcium arsenate were limited to less than 400 pounds per acre (114).

Chlorates. Of the various chemicals used in weed control, the chlorates, particularly sodium chlorate, have been most widely used. As early as 1901 potassium chlorate was employed to destroy prickly pear. As the results were not especially promising, the work attracted little attention. In 1923, dilute sodium chlorate was reported to be effective in weed control (236). A little later, Korsmo destroyed 11 species of perennial weeds by one application of 3.16 gallons per square yard of a 5% solution (213).

Soon after the earliest chlorate investigations, published reports by American investigators appeared. Intensive Kansas studies in the control of field bindweed showed that a 12.5% solution of sodium chlorate was most effective and that treatments should be made about the time the plants were in full bloom (223, 224). In Minnesota, sodium chlorate proved to be the best of several chemicals tested. The proprietary compound Atlacide was more expensive than the straight sodium chlorate and did not give equal results, pound for pound.

While much of the chemical weed control work has been on field bindweed, sodium chlorate has been effective on other weeds. Harper (163) effectively treated Johnson grass with a 12½% solution applied 100 gallons per acre in May and again about August 1. In New South Wales Johnson grass was controlled with a 450 gallons per acre application of a 10% solution (54). One investigator found sodium chlorate and Atlacide to be equally effective in the control of Johnson grass (198). Many other investigations have been made of sodium chlorate as a weed eradicant (12, 68, 84, 85, 90, 105, 154, 171, 183, 186, 188, 227, 232, 235, 245, 257, 271, 279, 310, 322 and 379).

Most investigators favor sodium chlorate over the other chlorates. Magnesium and calcium chlorates have been suggested as substitutes (225). Aslander (15) secured good results on Canada thistle with dry potassium chlorate. A French investigator (133) secured equally good results with potassium and sodium chlorates. Today nearly all workers are using sodium chlorate in preference to the other chlorates.

Numerous problems confront the user of chemicals for weed control. The method, time and rate of application must be determined for each chemical used. Wide differences in effectiveness may result from a variation in the methods of use. For example,

in North Dakota dry applications of sodium chlorate were effective in controlling bindweed, provided there was sufficient rainfall to carry the chemical into the soil and the temperature was relatively low to prevent chlorate decomposition (173). Dry applications were effective in the control of Canada thistle in New York (15). Muenscher (259) recommends the dry treatment for perennial weeds in general. Minnesota trials show the dry salt to be as effective as the spray method (402). Use of the dry salt obviates the purchase of expensive spray equipment and reduces the fire hazard greatly, as chlorate is highly explosive when mixed with dust or organic matter, and several disastrous fires have resulted from careless use. Release of the oxygen contained in the chlorate molecule results in a very high temperature and a fire which can not be extinguished with water.

At Cornell fall applications of chlorate are recommended (15). Similar recommendations have been made by other investigators (259, 329, 402). Harper (163) reported fall applications to be ineffective in the control of Johnson grass. In Minnesota applications before August 1 did not penetrate the soil more than two feet, but in treatments after August 1, penetration was greater, being directly correlated with the accumulation of soil moisture (55).

Recommended rates of applying sodium chlorate are not the same in all areas. Aslander (15) destroyed Canada thistles with 200 kgm. per hectare. In Ohio (398) a total of four pounds per square rod was most satisfactory, while in Minnesota (402) the general recommendation is about 500 pounds per acre. If additional treatments are necessary, chemicals may be applied to small areas the following year.

It is generally believed that chlorate enters the plant through the root and thus is most effective when it reaches the soil. Removal of plant top growth may expedite the effectiveness of the chemical (234). The organic matter present may affect the efficiency of the treatment, as chlorate toxicity has been shown to be inversely correlated with soil fertility (91). It was believed that seasonal variations in the response of plants to treatment may be explained on the basis of nitrate concentrations as affected by leaching, temperature, absorption by plants, and nitrification. More recent work at Wisconsin has given similar results (330, 331). Increments of organic matter markedly decreased chlorate toxicity. Soils con-

taining nitrates may be leached to lower levels and thus alter the toxicity of chlorate at different root levels (321). It is possible that the ineffectiveness of chlorate under conditions of high levels of fertility may be due to microbial activity rather than to the presence of organic matter. High organic matter with moisture and warmth results in greater microbial activity and reduced effectiveness of chlorate (264).

Latshaw and Zahnley (223) found that sodium chlorate reduced the nitrifying power of soils, the effect being greater on the later treated soils. Aslander (16) reported no effect upon the ammonification process of soils which had received from 500 to 2,000 p.p.m. of chlorate. Accumulation of nitrates was diminished when the chemical was applied in the fall. There was no influence on the ammonification and nitrification processes the following spring. Chlorate had little or no effect on earth worms and none on protozoa. Species of *Penicillium, Aspergillus* and *Fusarium* grew on top of hay infusions containing N/10 $NaClO_3$, and numerous bacteria developed in the solution. Another investigator (217) reports that chlorate was injurious to microbiological life in the soil and to nitrification. It was shown that both inoculation and treatment with ammonium sulphate gave increases in survival of red clover plants on land previously treated with chlorate (152). Decomposition of chemicals in the soil may exert a marked effect on soil microbiological activity and subsequent growth (42).

Hurd-Karrer (192) has reviewed the literature on soil conditions affecting the herbicidal action of chlorates. In Germany no unfavorable effects of sodium chlorate upon soil reaction or physical structure were evident (292). Toxic effects on soil under Canadian conditions are discussed by Bowser and Newton (42).

Weeds growing under irrigated conditions present different problems than those in more humid areas and require a different amount of chlorate for effective control (185). Chlorate toxicity is usually greatest in acid soils and least in alkaline soils. Soils which were limed (pH 7.5–8) showed the least toxicity (191).

The tolerance of susceptible plants to chlorate is a measure of the quantity present in the soil. *Tradescantia virginica* Wats., hemp, tomatoes, beans and sunflowers were good testers, since all were more or less injured by less than 10 p.p.m. in the soil (356). The resistance of crop plants is of great importance, since under farming

conditions the aim is to return the treated land to productivity as soon as possible. Hurd-Karrer found barley, sunflowers and spinach to be most sensitive to chlorate in greenhouse tests. Wheat was nearly as tolerant as oats; rye was definitely less tolerant and barley the most susceptible of the small grain crops. Flax was nearly as tolerant as oats. Vetch, sweet clover, and alfalfa were among the more resistant crops, while the sorghums tested were susceptible (190).

No discussion of chlorates would be complete without a consideration of the poisonous characteristics of the salt. When fed in measured doses, from 18 to 400 grams were injurious to average sized dairy cows (123). A full grown steer became ill after having access for two weeks to a lick of one part bonemeal and two parts sodium chlorate (333). Care must be exercised when animals graze on areas treated with herbicides (254).

Other Chemicals. Many types of chemicals have been tested by research workers in their efforts to find an effective but economical weed eradicant that is free from the many disadvantages of those herbicides generally used.

Carbon bisulphide, a volatile liquid whose gas spreads through the soil, has been used as a weed killer for several years. In Colorado it proved successful in destroying several long-lived perennials (317). In general, results have been good in dry areas but not so encouraging in more humid regions. A prime disadvantage of carbon bisulphide is its explosive nature which renders its use extremely dangerous.

Harvey (166) is generally credited with doing the first experimental work with ammonium thiocyanate as a weed herbicide. Under Minnesota conditions applications of 10 pounds per square rod made the soil sterile for at least four months. A two pound application sterilized the soil for two to four weeks, and subsequently gave a definite stimulation of growth, due to the release of nitrogen. Applications of 10 pounds of the salt dissolved in water to each 1,000 square feet usually killed all annual weeds (98). Several investigators have tested the thiocyanates and found them generally successful with shallow rooted weeds but ineffective in destroying deep rooted persistent perennials. Further studies are needed to determine their place as possible adjuncts to other herbicides. Studies have shown ammonium thiocyanate to be inferior to

chlorate in destroying leafy spurge (26). The chemical exerts definite effects upon nitrification and soil organisms in general (327), and it has been reported as toxic to livestock, especially cattle (267).

Boron has been suggested as an economical herbicide, and many recent investigations indicate that it has a place in weed control. California investigators state, on the contrary, that boron compounds will find but limited use in weed control (93). Under their conditions they believe that a combination of sodium chlorate with some one of the cheap boron ores may prove desirable. Trials in North Dakota showed no advantage of borax over other herbicides (174). Unpublished results at the Minnesota Station indicate that borax may have a place in weed control, as generally good results have been secured in the eradication of long-lived perennials. An unsolved problem is the length of time the boron may sterilize the soil and prevent the growth of desirable plants. Its non-poisonous and non-inflammable characteristics make its use free from the hazards of chlorates.

Blackman (36) reported that aluminum salts, copper salts, sodium bisulphite and ammonium thiocyanate were ineffective. Both sodium bichromate and sodium arsenite were less effective than sodium chlorate. Similar work at Cornell (15) showed sodium thiocyanate, sodium cyanide and sodium arsenite to be inferior to chlorate. One investigator proposes the substitution of sodium bromate, in part, in a mixture of sodium chlorate (180). More than 150 chemicals were tested for the eradication of many species of *Ribes* (273). Paint was reported as effective in killing weeds (309). Certain chemicals have been used as catalysts to increase the effectiveness of the principal herbicide. Salts of magnesium, cobalt, nickel and vanadium pentoxide were used to intensify the action of sodium chlorate (101). Bates (31) also secured improved results from the use of vanadium pentoxide as a catalyst.

Some investigators have used fertilizers to destroy weeds (231, 338, 339). Kainite destroyed poison ivy when applied to the wet foliage (63). Sodium dichromate lowered the yields of wheat in the season applied but tended to increase yields the following year (266). Sodium ethyl xanthate and ethylene oxide have been proposed as weed eradicants (167, 169). Tetrachlorethane was effective in destroying field bindweed (22). Water hyacinth was

checked by sodium pentachlorphenate (182). Quack grass and field bindweed were not destroyed by petroleum oils containing differing amounts of furfural (58).

Zinc sulphate was effective in destroying germinating weed seed roots without injuring the evergreen roots with which they were growing (6). Thallium sulphate proved very toxic in sterilizing soils (88). Liquid chloropicrin has been used to destroy weed seeds in composted soil (184) and weeds in turf (144, 248). This chemical exerted a marked effect upon nitrification and ammonification in the soil (357). Other trials with miscellaneous herbicides show considerable difference in toxicity (35, 47, 72, 73, 74, 75, 76, 265).

How Chemicals Kill

According to Aslander (16), dilute sulphuric acid sprays do not plasmolyze plant cells. The acid penetrates into the cells, unites with the magnesium atom in the chlorophyll molecule and decomposes the protoplasm. The chloroplasts are destroyed but the cell walls usually are not affected.

Arsenical sprays kill the plant parts with which they come in contact, and their action in killing the roots of perennial weeds has been explained as being due to transport of the poison through the stems into the roots. Within the fog belt in California, arsenical sprays applied to bindweed in bloom killed many of the plants (150). After a period of dry hot weather, stems of bindweed cut under eosin solution carried the fluid to a considerable depth (92), and it was believed that the movement indicated subatmospheric pressure. "The poisonous nature of arsenic necessitates its transport through non-living channels in lethal concentrations. This practically limits its movement within the plant to the xylem and prescribes a high water deficit and particularly favorable conditions for application of the spray. These conditions are seldom met in actual practice".

Killing by leaf and stem absorption has been classified as local or remote, and it was believed possible that the arsenic could be carried downward into the roots along with elaborated plant food in that direction (196). In this way better killing at about the time of bloom than at other times was explained. Many factors influence the use of chemical weed killers (243).

The roots of plants to which chlorate had been applied were practically free from starch, while untreated plants had an abundance of reserve material in their roots (223). It was believed that the chlorate interfered with the photosynthetic activity of the plants and compelled them to draw on the reserve food supplies.

Harvey (165) offered the following explanation as to how ethylene oxide and sodium chlorate kill plants: "The tissues turn black and the cells die. Evidently the respiratory chromogens are so completely oxidized that they cannot function. They are oxidized to the pigment forms peculiar to each tissue".

The catalase activity of field bindweed roots growing in sodium chlorate treated soil was found to be lower than that in the roots of untreated plants. "It is probable also that the chlorate ion inhibits the other enzymatic activities of a plant in a similar way. It is possible that the more slowly acting but higher toxicity of the chlorates is due to the gradual decomposition within the plant tissues accompanied by a liberation of nascent oxygen" (263).

In *Nitella* there was no accumulation of the chlorate ion within the cytoplast when injury to the cells took place, and the quantity of the chlorate or chlorate ion fixed by the protoplast was very small. This indicated that the concentration of the chlorate was not materially lowered in the course of toxic action, a condition that would allow the chlorate solution to penetrate relatively easily and probably reach the vascular tissues of the plant. "Apparently the typical chlorate action may be exerted over a wide range of the concentrations and, after the initial plasmolytic action, the concentration does not materially affect the rate of injury". Addition of ammonium chloride to sodium chlorate intensified somewhat the chlorate action; on the other hand, addition of calcium chloride retarded the action (272).

Loomis *et al.* (234) also discuss absorption and movement of sodium chlorate. The action and problems relative to its use as an herbicide are explained by Crafts (86). The effectiveness of spray applications in control of field bindweed is dependent upon atmospheric conditions (200), and the poisonous ingredient is not the chlorate but the hypochlorite ion (253). Using copper nitrate solutions, Silversides reports on the method of penetration of herbicides into plants (336).

WEEDS OF THE TURF

Probably no other group of people is more aware of the weed menace than those who care for lawns. In general, the species which must be fought by the lawn caretaker are few, but some of them are so persistent that they prove real menaces. In addition to the following more specific treatments of the subject there are several general contributions (62, 103, 168, 247, 380, 393, 395, 404).

In a recent complete discussion of weed control in lawns, the primary requisites are clean cultivation before seeding, use of pure seed and clean top dressing, and adequate fertilization (261). The authors recommend sodium chlorate, one and one-half to two ounces in one gallon of water per 100 square feet, applied in early spring or late fall when the weather is cool. When crabgrass is in the seedling stage, one pound of sodium chlorate should be mixed with 20 quarts of sand and spread over 1,000 square feet. Seventy-five to 100 pounds of dry granulated iron sulphate in 50 gallons of water per acre applied as a fine spray may be used as an alternate in four to six applications at intervals of about 10 days.

Other workers, too, have reported on the use of sodium chlorate in controlling lawn weeds (148, 208, 262, 378). Fall applications are recommended for renovation work at the rate of one to one and one-half pounds per 1,000 square feet (391), and applications of two pounds per 1,000 square feet with three successive applications have proved effective on crabgrass and other common lawn weeds.

Applications of 1,000–2,000 lbs. of calcium cyanamide per acre on Bermuda grass lawns from December 1 to March 1 were successful in destroying annual weeds, but the chemical should not be used on bluegrass lawns (368, 369). Another worker recommends calcium cyanamide for the control of dandelions (341), while others report that lead arsenate was effective in controlling chickweed and crabgrass (270).

A 2% solution of sodium fluoride plus 1% soap destroyed or injured crabgrass with little injury to bluegrass (240). Another worker secured effective control of dandelion with copper nitrate (336), and copper sulphate, one pound per 100 square feet, was effective in killing certain weeds (181).

Ammonium sulphate, a commonly used nitrogenous fertilizer for lawns, is widely employed also in weed control. Rosette types were controlled by it (314), and addition of ferrous sulphate eradicated

mosses and clovers. Six pounds of $(NH_4)_2SO_4$ per 1,000 square feet may be applied in the early morning when the grass is wet with dew. Application in early spring or late fall, with water applied after a day or two, is a recommended practice (261). One investigator used it successfully at the rate of one-half ounce per square yard, either dry or as a 5% solution (one-half pound per gallon of water), to destroy weeds and white clover in lawns (69), and others have secured similar results (104, 270, 390). Addition of a soft soap as a spreader has been found to increase the effectiveness (120). Lead arsenate applications in October, December, February and April were effective on crabgrass, 20 to 25 pounds per 1,000 square feet usually giving almost complete control (394). Any potential bad after effect was overcome by liberal use of nitrogenous fertilizers.

One-half gallon of water-white kerosene (color Saybolt 23) to each 100 square feet of lawn has helped to control crabgrass, mouse ear chickweed and dandelions (402). Loomis (233) advises the use of straight-run kerosene with a boiling point range of 180° to 250° C. and an unsaturated hydrocarbon content of not more than 4% as a means of destroying dandelions in bluegrass lawns. The kerosene is applied at a rate of 200 gallons per acre two months before the end of the growing season, since it requires from two to three weeks for the grass to recover and this allows about six weeks for it to build up reserves for the winter. Dandelions were also controlled by using 126 cc. of mercurated ethyl stearate in 6½ gallons of kerosene applied to an area of 1,000 square feet (153), while other investigators used dichloroethyl ether (372) and paraffin oil (268). Others have secured good results in the control of dandelions and broad-leaved plantain by using Meo–181 and high grade kerosene, the best effects with least damage to bluegrass being secured when treatment was made between September 20 and October 1 (230).

Lawn Sinox was best for the control of chickweed when applied as a spray at a rate of four and one-tenth gallons per square rod in a 1:64 dilution.

BIBLIOGRAPHY

1. Aamodt, O. S. Control of wild oats. Univ. Alberta, Ext. Lft. 14. 1935.
2. Aamodt, O. S. and Platt, A. W. Resistance of wild oats and some common cereal varieties to freezing temperatures. Sci. Agr. **14**: 645–650. 1934.

3. Aldous, A. E. The eradication of brush and weeds from pasture lands. Jour. Am. Soc. Agron. **21**: 660–66. 1929.
4. ————. Relation of organic food reserves to the growth of some Kansas pasture plants. Jour. Am. Soc. Agron. **22**: 385–92. 1930.
5. Andrew, H. W. Weeds on the East-West Railway. Jour. Agr. S. Australia **20**: 982–3. 1917.
6. Anonymous. Zinc treatment to kill weed seeds. Science (Suppl.) **71**: XII. 1930.
7. ————. Weed destruction by chemicals. Nature **132**: 122–3. 1933.
8. ————. Bindweed eradication. Publ. by Kan. St. Bd. Agr. Dec. 1940.
9. Arny, A. C. Quack-grass eradication. Minn. Agr. Exp. Sta., Bul. 151. 1915.
10. ————. Eradicating perennial weeds in Minnesota. Minn. Agr. Exp. Sta., Spec. Bul. 140. 1931.
11. ————. Variations in the organic reserves in underground parts of five perennial weeds from April to November. Minn. Agr. Exp. Sta., Tech. Bul. 84. 1932.
12. ———— *et al.* Eradicating perennial weed with chlorates. Minn. Agr. Exp. Sta., Ext. Circ. 32. 1931 (Revised).
13. Arthur, J. C. A new weed exterminator. Science **37**: 19. 1913.
14. Aslander, A. Utspädd Svorvelsyra som Besprulninsmedal mot Ogras. Nord. Jordbrugsforsk. **3–4**: 126–46. 1925.
15. ————. Chlorates as plant poisons. Jour. Am. Soc. Agron. **18**: 1101–02. 1926.
16. ————. Experiments on the eradication of Canada Thistle, *Cirsium arvense*, with chlorates and other herbicides. Jour. Agr. Res. **36**: 915–34. 1928.
17. Atkeson, F. W. *et al.* Effect of bovine digestion and of manure storage on the viability of weed seeds. Jour. Am. Soc. Agron. **26**: 309–7. 1934.
18. Bakke, A. L. Leafy spurge, *Euphorbia esula* L. Ia. Agr. Exp. Sta., Res. Bul. 198. 1936.
19. ————. Control of leafy spurge (*Euphorbia esula* L.). Ia. Agr. Exp. Sta., Res. Bul. 222. 1937.
20. ————. The soil moisture relationship of European bindweed growing in corn. Jour. Am. Soc. Agron. **31**: 352–57. 1939.
21. ————. Experiments on the control of European bindweed. (*Convolulus arvensis* L.) Ia. Agr. Exp. Sta., Res. Bul. 259: 367–440. 1939.
22. ————. The use of tetrachlorethane in the eradication of the European bindweed. Jour. Am. Soc. Agron. **33**: 759–61. 1941.
23. ———— *et al.* Relation of root reserves to control of European bindweed. *Convolulus arvensis* L. Ia. Agr. Exp. Sta., Res. Bul. 254. 1939.
24. Ball, W. E. and French, O. C. Sulphuric acid for control of weeds. Cal. Agr. Exp. Sta., Bul. 596. 1935.
25. Ball, W. S. *et al.* Weed control. Cal. Agr. Exp. Sta., Ext. Circ. 97. 1940 (Revised).
26. Barnett, H. L. and Hanson, H. C. Control of leafy spurge and review of literature on chemical weed control. No. Dak. Agr. Exp. Sta., Bul. 277. 1934.
27. Barnum, Clyde C. The control of wild morning glory. Cal. Agr. Exp. Sta., Circ. 256. 1923.
28. Barr, C. G. Preliminary studies on the carbohydrates in the roots of bindweed. Jour. Am. Soc. Agron. **28**: 787–98. 1936.
29. ————. Organic reserves in the roots of bindweed. Jour. Agr. Res. **60**: 391–413. 1940.

30. ————. Reserve foods in the roots of whiteweed (*Cardaria draba* var. *repens*). Jour. Agr. Res. **64:** 725–40. 1942.
31. Bates, G. H. Vanadium pentoxide as a catalyst for sodium chlorate in weed destruction. Nature **148:** 753. 1941.
32. Batho, G. Field bindweed. Manitoba Dept. Agr., Circ. 138. 1939.
33. Bibbey, R. O. The influence of environment upon the germination of weed seeds. Sci. Agr. **16:** 141–150. 1935.
34. Bioletti, F. T. The extermination of morning glory. Cal. Agr. Exp. Sta., Circ. 69. 1911.
35. Bissey, R. and Butler, O. Experiments on the control of mustard. Jour. Am. Soc. Agron. **22:** 124–35. 1930.
36. Blackman, G. E. The relative toxicity of chemical weedkillers. Ann. App. Biol. **25:** 652–53. 1938.
37. ———— and Templeman, W. G. Eradication of weeds in cereal crops by sulphuric acid and other compounds. Jour. Agr. Sci. **26:** 368–90. 1936.
38. ————, ————. The nature of the competition between cereal crops and annual weeds. Jour. Agr. Sci. **28:** 247–71. 1938.
39. Bolley, H. L. The destruction of weeds in cereal grains by means of chemical solutions sprayed upon the foliage. No. Dak. Agr. Exp. Sta., 10th Ann. Rep. 25–6. 1900.
40. ————. Weeds and methods of eradication. No. Dak. Agr. Exp. Sta., Bul. 80. 1908.
41. Bonnet, M. Destruction de la cuscute. Jour. d'Agr. Prat. **61**(2): 916. 1897.
42. Bowser, W. E. and Newton, J. D. Decomposition and movement of herbicides in soils and effects on soil microbiological activity and subsequent crop growth. Canad. Jour. Res. **8:** 73–100. 1933.
43. Boyd, G. R. Clearing land of brush and stumps. U. S. Dept. Agr., Farm. Bul. 1526. 1929 (Revised).
44. Boyd, G. W. and Corkins, C. L. Wyoming weeds and their control. Wy. Agr. Exp. Sta., Circ. 33. 1940 (Revised).
45. Brenchley, W. E. Weeds on arable land and their suppression. Jour. Roy. Agr. Soc. England **76:** 14–37. 1915.
46. ————. Weeds of farm land. 1920.
47. ————. Spraying for weed eradication. Jour. Bath & West & So. Counties Soc. V. **19:** 1–20. 1925.
48. ———— and Warington, Katherine. Fallowing for weed suppression. Jour. Min. Agr., Gt. Brit. **40:** 32–41. 1933.
49. ————, ————. The weed seed population of arable soil. I. Numerical estimation of viable seeds and observations on their natural dormancy. Jour. Ecol. **18:** 235–72. 1930.
50. ————, ————. The weed seed population of arable soil. II. Influence of crop, soil, and methods of cultivation upon the relative abundance of viable seeds. Jour. Ecol. **21:** 103–127. 1933.
51. ————, ————. The weed seed population of arable soil. III. The reestablishment of weed species after reduction by fallowing. Jour. Ecol. **24:** 479–501. 1936.
52. Britton, N. L. and Brown, A. An illustrated flora of the northern United States, Canada, and the British Possessions. 1923.
53. Brown, B. A. Effect of time of cutting on the elimination of bushes in pastures. Jour. Am. Soc. Agron. **22:** 603–05. 1930.
54. Brown, C. W. Johnson grass troublesome on lucerne flats. Agr. Gaz. New So. Wales **50:** 595–8. 1939.
55. Brown, Wm. J. N. Some soil moisture relationships in field bindweed (*Convolulus arvensis* L.) control. Thesis, Univ. Minn. 1942.
56. Brown, E. O. and Porter, R. H. The viability and germination of seeds of *Convolulus arvensis* L. and other perennial weeds. Ia. Agr. Exp. Sta., Res. Bul. 294: 475–504. 1942.

57. Brown, J. G. and Streets, R. B. Sulphuric acid spray a practical means for the control of weeds. Ariz. Agr. Exp. Sta., Bul. 128. 1928.
58. Buckardt, H. L. Effectiveness of furfural petroleum combination in eradicating certain noxious weeds. Jour. Am. Soc. Agron. **28:** 437–42. 1936.
59. Bull, C. P. Corn. Minn. Agr. Exp. Sta., Bul. 149. 1915.
60. ————. Weeds in the fields, gardens, and lawns. Minn. State Dept. Agr., Bul. 43. 1925.
61. ————. The weed control program. Proc. Assoc. Off. Seed Anal. No. Am. 117–20. 1936.
62. Burcalow, F. V. *et al.* The duration of the effects of renovation in the control of weeds and white grubs (*Phyllophaga sp.*) in permanent bluegrass pastures. Jour. Am. Soc. Agron. **32:** 15–22. 1940.
63. Butler, O. The use of Kainite for the control of poison ivy. Jour. Am. Soc. Agron. **24:** 979–81. 1932.
64. Call, L. E. and Sewell, M. C. The relation of weed growth to nitric nitrogen accumulation in the soil. Jour. Am. Soc. Agron. **10:** 35–44. 1918.
65. ———— and Getty, R. E. The eradication of bindweed. Kan. Agr. Exp. Sta., Circ. 101. 1923.
66. Carn, K. G. Arsenic compounds. Their use as weed killers. Agr. Gaz. New So. Wales **50:** 195, 226. 1939.
67. Cates, J. S. and Cox, H. R. The weed factor in the cultivation of corn. U. S. Dept. Agr., Bur. Pl. Ind., Bul. 257. 1912.
68. Chepil, W. S. The eradication of perennial weeds with sodium chlorate. Proc. World's Grain Exh. Conf. **2:** 201–6. 1933.
69. Clarke, G. H. The eradication of weeds. Jour. Dept. Agr. So. Australia **41:** 860–5. 1938.
70. Clawson, A. B. and Moran, E. A. Toxicity of arrowgrass for sheep and remedial treatment. U. S. Dept. Agr., Tech. Bul. 580. 1937.
71. Cole, H. E. and Holch, A. E. The root habits of certain weeds of southeastern Nebraska. Ecology **22:** 141–7. 1941.
72. Cook, W. H. Chemical weed killers. I. Relative toxicity of various chemicals to four annual weeds. Canad. Jour. Res. **15:** C. 299–323. 1937.
73. ————. Chemical weed killers. IV. Relative toxicities and loci of absorption of selected chemicals applied to perennials. Canad. Jour. Res. **15:** C. 451–60. 1937.
74. ————. Chemical weed killers. V. Relative toxicity of selected chemicals to plants grown in culture solution, and the use of relative growth rate as a criterion of toxicity. Canad. Jour. Res. **15:** C. 520–37. 1937.
75. ————. Chemical weed killers. II. Factors affecting estimation of toxicity of leaf sprays. Canad. Jour. Res. **15:** 380–90. 1938.
76. ———— *et al.* Chemical weed killers. III. Relative toxicity of several chemicals to perennials under field conditions. Canad. Jour. Res. **15:** 442–49. 1937.
77. Cooley, C. L. Wild bramble eradication. N. Y. (Geneva) St. Agr. Exp. Sta., Bul. 674. 1936.
78. Corkins, C. L. Methods of noxious weed control. Reclam. Era **30:** 21–24. 1940.
79. Corkins, C. L. and Elledge, A. B. Continuous burning to eradicate noxious weeds. Reclam. Era **30:** 140–42. 1940.
80. Cox, H. R. Eradication of ferns from pasture lands in the eastern United States. U. S. Dept. Agr., Farm. Bul. 687. 1936 (Revised).
81. ————. Weeds: How to Control Them. U. S. Dept. Agr., Farm. Bul. 660. 1939 (Revised).
82. Crafts, A. S. The use of arsenical compounds in the control of deep-rooted perennial weeds. Hilgardia **7:** 361–72. 1933.

83. ————. Sulphuric acid as a penetrating agent in arsenical sprays for weed control. Hilgardia **8:** 125–47. 1933.
84. ————. Factors influencing the effectiveness of sodium chlorate as a herbicide. Hilgardia **9:** 437–57. 1935.
85. ————. The toxicity of sodium arsenite and sodium chlorate in four California soils. Hilgardia **9:** 461–98. 1935.
86. ————. Physiological problems connected with the use of sodium chlorate in weed control. Pl. Physiol. **10:** 699–711. 1935.
87. ————. Plot tests with sodium arsenite and sodium chlorate as soil sterilants in California. Cal. State Dept. Agr., Bul. 24: 247–259. 1935.
88. ————. Some effects of thallium sulfate upon soils. Hilgardia **10:** 377–97. 1936.
89. ————. The acid arsenical method in weed control. Jour. Am. Soc. Agron. **29:** 934–43. 1937.
90. ————. Toxicity studies with sodium chlorate in eighty California soils. Hilgardia **12:** 233–47. 1939.
91. ————. The relation of nutrients to toxicity of arsenic, borax, and chlorate in soils. Jour. Agr. Res. **58:** 637–71. 1939.
92. ———— and Kennedy, P. B. The physiology of *Convolvulus arvensis* (morning glory or bindweed) in relation to its control by chemical sprays. Pl. Physiol. **5:** 329–344. 1930.
93. ———— and Raynor, R. N. The herbicidal properties of boron compounds. Hilgardia **10:** 343–74. 1936.
94. ———— and Cleary, C. W. Toxicity of arsenic, borax, chlorate, and their combinations in three California soils. Hilgardia **10:** 401–13. 1936.
95. ———— and Rosenfels, R. S. Toxicity studies with arsenic in eighty California soils. Hilgardia **12:** 177–200. 1939.
96. ———— and Raynor, R. N. Principles of chemical weed control. The control of weeds. Imp. Bur. Past. & For. Crops, Herb. Pub. Ser., Bul. **27:** 38–54. 1940.
97. ———— *et al.* Plot tests with chemical soil sterilants in California. Cal. Agr. Exp. Sta., Bul. 648. 1941.
98. Cupery, M. E. and Cupery, H. Preliminary tests conducted to evaluate action of sulfamates as weed killers. DuPont Agr. News Letter **8:** 23–24. 1940.
99. Currie, G. A. Some Australian weed problems. The control of weeds. Imp. Bur. Past. & For. Crops, Herb. Pub. Ser., Bul. **27:** 113–30. 1940.
100. Dahl, A. S. Control of weeds and brush in pastures by mowing. U. S. Dept. Agr., Soil Cons. Serv., Mim. Lft. 1688. 1937.
101. Dancaster, E. A. Catalysts for sodium chlorate in weed destruction. Nature **150:** 737–38. 1942.
102. Darlington, H. T. *et al.* Some important Michigan weeds. Mich. Agr. Exp. Sta., Spec. Bul. 304. 1940.
103. Dawson, R. B. The control of weeds in lawns and fine turf. Ann. App. Biol. **25:** 653–59. 1938.
104. Deatrick, E. P. The spotting method of weed eradication. Science **71:** 487–88. 1930.
105. Deem, J. W. Control of weeds with chlorates. New Zealand Jour. Agr. **43:** 105–10. 1931.
106. Delwiche, E. J. Weeds menace some northern areas. Wis. Agr. Exp. Sta., Bul. 449: 79–80. 1940.
107. Detmers, Freda. Canada thistle, *Cirsium arvense*. Tourn. Ohio Agr. Exp. Sta., Bul. 414: 1–45. 1927.
108. Dexter, S. T. Response of quack grass to defoliation and fertilization. Pl. Physiol. **11:** 843–51. 1936.
109. ————. The winterhardiness of weeds. Jour. Am. Soc. Agron. **29:** 512–17. 1937.

110. ————. The drouth resistance of quack grass under various degrees of fertilization with nitrogen. Jour. Am. Soc. Agron. **29**: 568–76. 1937.
111. ————. Seasonal variations in drought resistance of exposed rhizomes of quack grass. Jour. Am. Soc. Agron. **34**: 1125–36. 1942.
112. DIEFFENBACH, E. M. Weed control machinery and control methods in Utah and Idaho. Agr. Eng. **21**: 437–8. 1940.
113. DJURLE, O. Svenska Vall-och Mosskulturfören [The weed problem. 3. Combatting weeds during the summer on muck land]. Kvartalsskr **3**: 219–224. 1941. [Biol. Abst. 20920. Nov., 1942].
114. DORMAN, C. *et al.* The effect of calcium arsenate upon the productivity of several important soils of the cotton belt. Jour. Am. Soc. Agron. **31**: 1020–28. 1939.
115. DREW, W. B. AND HELM, C. A. Representative Missouri weeds and their control. Mo. Agr. Exp. Sta., Bul. 433. 1941.
116. DROTTIJ, S. Harrowing to control weeds in cereals. U. S. Dept. Agr., Exp. Sta. Rec. **62**: 227. 1930. [Meddel. Centralanst. Försöksv. Jordbruksområdet (Sweden) No. 348. 1929].
117. DUNHAM, R. S. Perennial sow thistle. Minn. Agr. Exp. Sta., Ext. Circ. 26. 1928.
118. DURRELL, L. W. AND NEWSOM, I. E. Colorado's poisonous and injurious plants. Col. Agr. Exp. Sta., Bul. 455. 1939.
119. DYKSTRA, T. P. Weeds as possible carriers of leaf roll and rugose mosaic of potato. Jour. Agr. Res. **47**: 17–32. 1933.
120. ENGLEDOW, F. L. AND WOODMAN, R. M. The use of a wetter in weed spraying. Jour. Min. Agr., Gt. Brit. **42**: 663–66. 1935.
121. ESSARY, S. H. Control of dodder in lespedeza. Tenn. Agr. Exp. Sta., Circ. 22. 1928.
122. EVANS, L. S. Bindweed control methods. Neb. Agr. Exp. Sta., Ext. Circ. 145. 1940.
123. FITCH, C. P. *et al.* Toxicity of sodium chlorate ($NaClO_3$) for cattle. Cornell Vet. **19**: 373–75. 1929.
124. FLEETWOOD, J. R. Field bindweed and methods of control. Mo. Agr. Exp. Sta., Ext. Circ. 387. 1938.
125. FLEMING, C. E. AND BRENNEN, C. A. White Top—Holding it under control by cultivation, followed by the establishment of a sod of pasture grasses and clovers. Nev. Agr. Exp. Sta., Bul. 149. 1938.
126. FRANZKE, C. J. AND HUME, A. N. Field bindweed. So. Dak. Agr. Exp. Sta., Bul. 305. 1936.
127. FRAZIER, J. C. Advantages of a fourteen-day interval of cultivation for the control of field bindweed, *Convolvulus arvensis* L. Am. Jour. Bot. **28**(10): 12s. 1941.
128. ————. Amount, distribution, and seasonal trend of certain organic reserves in the root system of field bindweed, *Convolvulus arvensis* L. Pl. Physiol. **18**: 167–184. 1943.
129. FRENCH, O. C. Application of sulphuric acid for weed control. Agr. Eng. **17**: 339–40. 1936.
130. ————. Equipment for chemical weed control. Agr. Eng. **21**: 487–8. 1940.
131. ———— AND BALL, W. E. A study of suitable equipment for applying sulphuric acid for weed control. Agr. Eng. **15**: 411–13. 1934.
132. FROMM, F. The eradication of nut grass. Science **96**: 337–38. 1942.
133. FRON, G. ET BERTRAND, R. Contribution à l'étude de l'influence des chlorates sur la végétation. Ann. Agron. **4**: 1–25. 1934.
134. FUELLEMAN, R. F. AND GRABER, L. F. Renovation and its effect on the populations of weeds in pastures. Jour. Am. Soc. Agron. **30**: 616–23. 1938.
135. GARMAN, H. Some Kentucky weeds and poisonous plants. Ky. Agr. Exp. Sta., Bul. 183. 1914.

136. GATES, F. C. Weeds in Kansas. Rep. Kan. State Bd. Agr. **60**: (243). 1941.
137. GEORGIA, ADA. Manual of weeds. 1914.
138. GERLACH, H. W. Bindweed control by clean cultivation. Agr. Eng. **19**: 219. 1938.
139. GIMINGHAM, C. T. AND TATTERSFIELD, F. Laboratory and field experiments on the use of 3:5-dinitro-o-cresol and the sodium salt for winter spraying. Jour. Agr. Sci. **17**: 162–80. 1927.
140. GODEL, G. L. Some considerations in regard to experiments with chemical herbicides. Canad. Jour. Res. **7**: 499–519. 1932.
141. ————. The chemical control of annual weeds in growing crops. Proc. World's Grain Exh. & Conf. Regina, Canada. Vol. 2: 207–13. 1933.
142. ————. Relation between rate of seeding and yield of cereal crops in competition with weeds. Sci. Agr. **16**: 165–68. 1935.
143. ————. Cereal growing on weedy land in northeastern Saskatchewan. Effects of heavy seeding with the use of fertilizer on the development of weeds and crops. Sci. Agr. **19**: 21–32. 1938.
144. GODFREY, G. H. The control of nut grass with chloropicrin. Soil Sci. **47**: 391–96. 1939.
145. GRAHAM, R. AND MICHAEL, V. M. White snakeroot poisoning. Ill. Agr. Exp. Sta., Circ. 436. 1935.
146. GRANDFIELD, C. O. The relation of organic food reserves to the effect of cutting pasture weeds at different stages of growth. Jour. Am. Soc. Agron. **22**: 709–13. 1930.
147. GRAND, C. V. AND HANSEN, A. A. Poison ivy and poison sumac and their eradication. U. S. Dept. Agr., Farm. Bul. 1166. 1929 (Revised).
148. GRAU, F. V. Use of sodium chlorate and other chemicals in controlling turf weeds. U. S. Golf Assoc., Bul. Green Sect. **13**: 154–79. 1933.
149. GRAY, A. Gray's new manual of botany. 1908.
150. GRAY, G. P. Spraying for the control of wild morning glory within the fog belt. Cal. Agr. Exp. Sta., Circ. 168. 1917.
151. GRESS, E. M. Pennsylvania weeds. Pa. Dept. Agr., Bul. 558. 1938.
152. HAINES, W. E. The effect of seed inoculation and of a nitrogen fertilizer on the survival of red clover plants growing in soil previously treated with sodium chlorate. Jour. Am. Soc. Agron. **25**: 181–3. 1933.
153. HANLEY, J. H. AND WEINARD, F. F. The chemical eradication of lawn weeds. Proc. Am. Soc. Hort. Sci. **35**: 845–9. 1937.
154. HANSEN, A. A. Eradicating quack grass with sodium chlorate. Jour. Am. Soc. Agron. **20**: 1120–23. 1928.
155. ————. Nineteen noxious weeds of Indiana. Purdue Agr. Exp. Sta., Circ. 106. 1922.
156. HANSON, H. C. AND RUDD, VELVA E. Leafy spurge. No. Dak. Agr. Exp. Sta., Bul. 266. 1933.
157. ————. Leafy spurge. No. Dak. Agr. Exp. Sta., Circ. 55. 1934.
158. ———— AND KLUENDER, W. Leafy spurge. No. Dak. Agr. Exp. Sta., Circ. 141. 1936.
159. ———— AND DICE, J. R. Milk tainting weeds and their control. No. Dak. Agr. Exp. Sta., Circ. 143. 1936.
160. HARDY, E. A. Tillage in relation to weed root systems. Agr. Eng. **19**: 435–8. 1938.
161. ————. Weed control in western Canada. Agr. Eng. **21**: 476. 1940.
162. HARMON, G. W. AND KEIM, F. D. The percentage and viability of weed seeds recovered in the feces of farm animals and their longevity when buried in manure. Jour. Am. Soc. Agron. **26**: 762–67. 1934.
163. HARPER, H. J. The use of sodium chlorate in the control of Johnson grass. Jour. Am. Soc. Agron. **22**: 417–22. 1930.

164. Harris, L. E. and Hyslop, G. R. Selective sprays for weed control in crops. Ore. Agr. Exp. Sta., Bul. 403. 1942.
165. Harvey, R. B. The action of toxic agents used in the eradication of noxious plants. Jour. Am. Soc. Agron. **23**: 481–89. 1931.
166. ———. Ammonium thiocyanate as a weed eradicant. Jour. Am. Soc. Agron. **23**: 944–946. 1931.
167. ———. Use of ethylene oxide for the eradication of pests. Science **73**: 100–01. 1931.
168. ——— and Larson, A. H. Common weeds of lawns. Seed Trade Buyers Guide. Pub. by Seed World. 70–87. 1940.
169. ——— *et al.* Sodium ethyl xanthate as a plant poison. Science **84**: 356. 1936.
170. Hayden, A. Distribution and reproduction of Canada thistle in Iowa. Am. Jour. Bot. **21**: 355–73. 1934.
171. Helgeson, E. A. Perennial peppergrass in North Dakota. No. Dak. Agr. Exp. Sta., Bi. Bul. 1(3) : 9–12. 1939.
172. ———. Russian knapweed and perennial peppergrass. No. Dak. Agr. Exp. Sta., Bul. 292. 1940.
173. ———. Control of field bindweed by dry chlorates. No. Dak. Agr. Exp. Sta., Bi. Bul. 4(1) : 7–8. 1941.
174. ———. Bindweed control by sodium arsenate, borax, and sodium chlorate. No. Dak. Agr. Exp. Sta., Bi. Bul. 4(3) : 14–15. 1942.
175. ——— and Thompson, E. J. Grazing in relation to the control of leafy spurge. Science **88**: 57. 1938.
176. ——— and Gerbracht, Dorothea. Chemical control of annual weeds in flax and grain fields. No. Dak. Agr. Exp. Sta., Bi. Bul. 3(2) : 7–10. 1940.
177. Helm, C. A. Corn in Missouri. II. Field methods that increase the corn crop. Mo. Agr. Exp. Sta., Bul. 185. 1921.
178. ———. Johnson grass. Mo. Agr. Exp. Sta., Ext. Lft. 45. 1936.
179. Henze, G. La cuscute et sa destruction. Jour. d' Agr. Prat. 61(2) : 815–816. 1897.
180. Hessenland, M. *et al.* Die Wirkung von Chlorat, Bromat, und Jodat auf Pflanzenwuchs. Ang. Chemie **46**: 577–79. 1933.
181. Hill, A. Trials of weed killers on garden paths at Craibstone. Scot. Jour. Agr. **11**: 203–9. 1928.
182. Hirsch, A. A. Toxic effects of sodium pentachlorphenate and other chemicals on water hyacinth. Bot. Gaz. **103**: 620–1. 1942.
183. Hopper, W. C. The eradication of weeds by chemical agents: A brief review of literature. Sci. Agr. **10**: 128–35. 1929.
184. Howard, F. L. and Stark, F. L. Chemical soil fumigation for more luxurious growth and weed control. Seed World **44**: 12–13. 1938.
185. Hulbert, H. W. *et al.* Controlling perennial weeds with chlorates. Jour. Am. Soc. Agron. **22**: 423–33. 1930.
186. ——— *et al.* Methods affecting the efficiency of chlorate weed killers. Id. Agr. Exp. Sta., Bul. 189. 1931.
187. ——— *et al.* The eradication of *Lepidium draba*. Jour. Am. Soc. Agron. **26**: 858–64. 1934.
188. ——— and Benjamin, L. V. Dry application of chlorates. Id. Agr. Exp. Sta., Circ. 74: 1–8. 1935.
189. Hume, A. N. and Sloan, S. L. Quack grass and western wheat grass. So. Dak. Agr. Exp. Sta., Bul. 170. 1916.
190. Hurd-Karrer, Annie M. Comparative susceptibility of crop plants to sodium chlorate injury. U. S. Dept. Agr., Tech Bul. 648. 1940.
191. ———. Chlorate toxicity and persistence in relation to soil reaction. Jour. Agr. Res. **63**: 481–94. 1941.
192. ———. Soil conditions affecting herbicidal action of chlorates: A literature review. U. S. Dept. Agr., Bur. Pl. Ind., Agr. Res. Adm., [Mim.] 1942.

193. HURST, EVELYN. The poison plants of New South Wales. 1942.
194. JACKMAN, E. R. *et al.* Control of perennial weeds in Oregon. Ore. Agr. Exp. Sta., Ext. Bul. 510. 1938.
195. JOHNSON, A. A. AND DEXTER, S. T. The response of quack grass to variations in height of cutting and rates of application of nitrogen. Jour. Am. Soc. Agron. **31**: 67–76. 1939.
196. JOHNSON, E. Recent developments in use of herbicides in California. Cal. Dept. Agr., Bul. 17: 7–16. 1928.
197. ————. The puncture vine in California. Cal. Agr. Exp. Sta., Bul. 528. 1932.
198. JONES, T. N. *et al.* Weed control and cotton tillage on blackbelt (prairie) soils. Miss. Agr. Exp. Sta., Tech. Bul. 29. 1941.
199. KEIM, F. D. *et al.* Bindweed eradication. Nebr. Agr. Exp. Sta., Circ. 50. 1938.
200. KENNEDY, P. B. AND CRAFTS, A. S. The application of physiological methods to weed control. Pl. Physiol. **2**: 503–06. 1927.
201. ————, ————. The anatomy of *Convolvulus arvensis*, wild morning glory or field bindweed. Hilgardia **5**: 591–622. 1931.
202. KEPHART, L. W. Quack grass. U. S. Dept. Agr., Farm. Bul. 1307. 1931 (Revised).
203. ————. The farm weed problem in America. The control of weeds. Imp. Bur. Past. & For. Crops, Herb. Pub. Ser., Bul. 27: 28–37. 1940.
204. KIESSELBACH, T. A. *et al.* Tillage practices in relation to corn production. Neb. Agr. Exp. Sta., Bul. 232. 1928.
205. ———— *et al.* Bindweeds and their control. Neb. Agr. Exp. Sta., Bul. 287. 1934.
206. KILTZ, B. F. Perennial weeds which spread vegetatively. Jour. Am. Soc. Agron. **22**: 216–34. 1930.
207. KINCH, R. C. Nebraska weeds. Neb. Dept. Agr. & Insp. Rev., Bul. 101. 1939.
208. ———— AND KEIM, F. D. Eradication of bindweed in bluegrass lawns. Jour. Am. Soc. Agron. **29**: 30–39. 1937.
209. KIRK, L. E. AND PAVYLCHENKO, T. K. Vegetative propagation of wild oats, *Avena fatua*, and other economically important species of *Aveneae* and *Hordeae*. Canad. Jour. Res. **7**: 204–20. 1932.
210. KONUROV, I. G. The system of cutting *Convolvulus arvensis* L. on fallows. Dokl. Vsesojuz. Akad. Seljskohoz. Nauk. **19**: 3–9. 1939. [Herbage Abs. **10**: No. 1875. 1940.]
211. KORSMO, E. The viability of weed seeds after passing through the digestive tract of farm animals. U. S. Dept. Agr., Exp. Sta. Rec. **26**: 839–000. 1912. [Trans. from Tidsskr. Norske Landbr. **18**: 223–30. 1911].
212. ————. Oni Bekjaenpelse au. Ugraes I. Appen Aker [Control of weeds on arable land]. (Norway) Landbr. Dept. Smaaskr. No. 4: 1–16. 1917.
213. ————. Natrium klorat ($NaClO_3$) some Ugraes draepende middel [Sodium chlorate as a remedy against weeds]. Norsk Landmandsblad **46**: 146–48. 1927.
214. ————. Unkräuter in Ackerbau der Neuzeit [Weeds in modern farming]. 580 pages. 1930.
215. ————. Underskelser a årene 1916–23 over ugressets skadevirkninger og dets bekjempelse i åkerbrukeh. Meld. Norg. Lanbr. Hoisk. **12**: 305–716. 1932.
216. ————. Weed seeds. Gyldendal Norsk Forlag. 175 pp. 1935.
217. KOTT, S. A. On application of chlorates for weed control. Himiz. Soc. Zemled. No. 5, 112. 1938. [Trans. in Herb. Abs. **9**: No. 440. 1939.]
218. KUHN, J. Biologischer Daseinskampf zwischen Unkraut und Kulturpflanze. Mitt. Deut. Landw. **47**: 7–8. 1932.

219. ————. Daseinskampf zwischen Blattfrucht und Unkraut. Mitt. Deut. Landw. **47:** 40–2. 1932.
220. Larson, A. H. *et al.* Farmstead weeds. Seed Trade Buyers Guide. Pub. by Seed World. 65–82. 1941.
221. ———— and Harvey, R. B. Common weeds. Seed Trade Buyers Guide. Pub. by Seed World. 109–24. 1938.
222. ———— *et al.* Poisonous plants. Seed Trade Buyers Guide. Pub. by Seed World. 105–22. 1939.
223. Latshaw, W. L. and Zahnley, J. W. Experiments with sodium chlorate and other chemicals as herbicides for field bindweed. Jour. Agr. Res. **35:** 757–67. 1927.
224. ————, ————. Killing field bindweed with sodium chlorate. Kans. Agr. Exp. Sta., Circ. 136. 1928.
225. ————, ————. Magnesium and calcium chlorate as substitutes for sodium chlorate for killing field bindweed. Jour. Am. Soc. Agron. **20:** 1329. 1928.
226. Lee, O. C. Johnson grass and its control in Indiana. Purdue Agr. Exp. Sta., Ext. Lft. 201. 1936.
227. ————. European bindweed and its control in Indiana. Purdue Agr. Exp. Sta., Ext. Lft. 206. 1937.
228. Leith, B. D. Weed killing more important than mulching in corn cultivation. Wis. Agr. Exp. Sta., Bul. 449. 77. 1940.
229. Levy, E. B. Pasture weeds. The control of weeds. Imp. Bur. Past. & For. Crops, Herb. Pub. Ser., Bul. **27:** 144–52. 1940.
230. Litzenberger, S. C. and Post, A. H. Selective sprays for the control of weeds in Kentucky blue grass lawns. Mont. Agr. Exp. Sta., Bul. 411. 1943.
231. Long, H. C. Suppression of weeds by fertilizers and chemicals. 57 pp. 1934.
232. ———— and MacDowall, R. K. Some chemical methods of weed destruction. Jour. Roy. Agr. Soc. Eng. **96:** 22–44. 1935.
233. Loomis, W. E. The control of dandelions in lawns. Jour. Agr. Res. **56:** 855–68. 1938.
234. ———— *et al.* Chlorates as herbicides. Science **74:** 485. 1931.
235. ———— *et al.* The absorption and movement of sodium chlorate when used as an herbicide. Jour. Am. Soc. Agron. **25:** 724–39. 1933.
236. Loyer, M. Emploi des chlorates pour la destruction des herbes dans les céréals de printemps. Compt. Rend. Acad. Agr. France **9:** 957–60. 1923.
237. Lunn, W. M. *et al.* Tobacco following bare and natural weed fallow and pure stands of certain weeds. Jour. Agr. Res. **59:** 829–45. 1939.
238. Lynes, F. F. Statistical analyses applied to research in weed eradication. Jour. Am. Soc. Agron. **27:** 980–87. 1935.
239. Manske, R. H. F. Chemical analyses as an aid to classification of poisonous plants. The control of weeds. Imp. Bur. Past. & For. Crops, Herb. Pub. Ser., Bul. 27. 27. 1940.
240. Marcovitch, S. Sodium fluoride as an herbicide. Jour. Am. Soc. Agron. **33:** 367. 1941.
241. Marsh, C. D. *et al.* The locoweed disease. U. S. Dept. Agr., Farm. Bul. 1054. 1936 (Revised).
242. McDonald, A. C. Arsenite of soda for destroying prickly pear. Agr. Jour. Dept. Agr. Cape Colony **5:** 112. 1892.
243. MacDowall, R. K. Some factors influencing the agricultural use of chemical weed killers. Ann. App. Biol. **25:** 648–52. 1938.
244. McGeorge, W. T. The effect of arsenite of soda on the soil. Hawaii Agr. Exp. Sta., Press Bul. 50: 1–16. 1915.
245. Meyer-Hermann, K. Unkrautbekämpfung mit natriumchlorathaltigen Mitteln. Mitt. Deut. Landw. **54:** 408–10. 1939.

246. Miller, D. Biological control of noxious weeds of New Zealand. The control of weeds. Imp. Bur. Past. & For. Crops, Herb. Pub. Ser., Bul. **27:** 153–7. 1940.
247. Monteith, J. J. Weed control in turf. The control of weeds. Imp. Bur. Past. & For. Crops, Herb. Pub. Ser., Bul. **27:** 55–67. 1940.
248. ———— and Rabbitt, A. E. Killing weed seeds in soil with chloropicrin (tear gas). Turf Culture **1:** 63–79. 1939.
249. Morettini, A. L'impiego dell acide solforice per combattere le erbe infeste nel frumento. Staz. Sper. Agr. Ital. **48:** 693–716. 1915.
250. Morgan, A. Experiments in hoary cress control. No. 1. Field trials. Jour. Dept. Agr., Victoria, Australia **29:** 406–16. 1931.
251. ————. Experiments in control of hoary cress. No. 2. Pot experiments. Jour. Dept. Agr., Victoria, Australia **29:** 504–15. 1931.
252. ————. Hoary cress control. Jour. Dept. Agr., Victoria, Australia **32:** 1–6, 40. 1934.
253. ————. The absorption and translocation of herbicides. Jour. Dept. Agr., Victoria, Australia **33:** 200–8. 1935.
254. Moore, G. R. Sodium chlorate poisoning in cattle. Jour. Am. Vet. Med. Assn. **99:** 50–2. 1941.
255. Muenscher, W. C. Leafy spurge and related weeds. Cornell Ext. Bul. 192. 1930.
256. ————. Perennial sow thistle and related weeds. Cornell Ext. Bul. 195. 1930.
257. ————. Killing perennial weeds with chlorates during winter. Cornell Univ. Agr. Exp. Sta., Bul. 542. 1932.
258. ————. Weeds of New York. Cornell Univ. Agr. Exp. Sta., Bul. 635. 1935.
259. ————. Controlling weeds with chlorates. Cornell Univ. Agr. Exp. Sta., Bul. 432. 1940.
260. ————. Weeds. 1941 (Revised).
261. ———— and Justice, O. L. The control of weeds in lawns. Cornell Ext. Bul. 431. 1940.
262. Murphy, H. F. The control of Bermuda grass through the use of chlorates. Jour. Am. Soc. Agron. **25:** 700–4. 1933.
263. Neller, J. R. Effect of chlorates upon the catalase activity of the roots of bindweed. Jour. Agr. Res. **43:** 183–89. 1931.
264. Nelson, R. T. Studies of microorganisms and chlorate persistence in soils treated with sodium chlorate. Thesis, Univ. Minn. 1942.
265. Neuweiler, E. Unkrautvertilgung im Getreide mit chemischen Mitteln. Landw. Jahrb., Schweiz. **53:** 1–13. 1939.
266. Newton, J. D. and Paul, A. D. Decomposition and movement of herbicides in soils, and effects on soil microbiological activity and subsequent crop growth. Canad. Jour. Res. **13:** 101–14. 1935.
267. Nilson, W. L. *et al.* Studies of the toxicity of ammonium thiocyanate for cattle. Cornell Vet. **22:** 347–53. 1932.
268. Nilsson-Leissner, G. Paraffin oil for dandelion control. Svenska Vall. Mossk. Fören. Kvartalsskr. **2:** 66–70. 1940. [Herb. Rev. **8:** 99–100. 1940; Herb. Abs. **10:** No. 1399. 1940.]
269. Norris, Elva B. L. Ecological study of the weed population of eastern Nebraska. Neb. Univ., Studies **39:** No. 2. 1939.
270. North, H. F. A. *et al.* Lawn grasses and their management. R. I. Agr. Exp. Sta., Bul. 264. 1938.
271. Offord, H. R. The chemical eradication of *Ribes*. U. S. Dept. Agr., Tech. Bul. 240. 1931.
272. ———— and d'Urbal, R. P. Toxic action of aqueous sodium chlorate on *Nitella*. Jour. Agr. Res. **43:** 791–810. 1931.
273. ———— *et al.* Chemical and mechanical methods of *Ribes* eradication in the white pines areas of the western states. U. S. Dept. Agr., Tech. Bul. 692. 1940.

274. Oswald, E. I. The effect of animal digestion and fermentation of manure on the vitality of seeds. Md. Agr. Exp. Sta., Bul. 128. 1908.
275. Oswald, W. L. and Boss, A. Minnesota weeds. I. Minn. Agr. Exp. Sta., Bul. 129. 1913.
276. ———, ———. Minnesota weeds. II. Minn. Agr. Exp. Sta., Bul. 139. 1914.
277. ———, ———. Minnesota weeds. III. Minn. Agr. Exp. Sta., Bul. 176. 1918.
278. Overpeck, J. C. Johnson grass eradication. N. M. Agr. Exp. Sta., Bul. 146. 1925.
279. Owen, O. Chlorate weed killers. Ann. App. Biol. **25**: 659–60. 1938.
280. Pammel, L. H. A manual of poisonous plants. 1911.
281. ———. Weeds of the farm and garden. 1911.
282. ———. Some weedy grasses injurious to livestock, especially sheep. Ia. Agr. Exp. Sta., Circ. 116. 1929.
283. ——— and King, C. M. Weed flora of Iowa. Ia. Geol. Survey, Bul. 4. 1926 (Revised).
284. ———, ———. A weed survey of Iowa. Jour. Am. Soc. Agron. **22**: 587–94. 1930.
285. Pavlychonko, T. K. Investigations relating to weed control in western Canada. The control of weeds. Imp. Bur. Past. & For. Crops, Herb. Pub. Ser., Bul. 27: 9–26. 1940.
286. ———. The place of crested wheat grass, *Agropyron cristatum* L. in controlling perennial weeds. Sci. Agr. **22**: 459–60. 1942.
287. ———. Quantitative study of the entire root systems of weed and crop plants under field conditions. Ecology **18**: 62–79. 1937.
288. ——— and Harrington, J. B. Competitive efficiency of weeds and cereal crops. Canad. Jour. Res. **10**: 77–94. 1934.
289. ———, ———. Root development of weeds and crops in competition under dry farming. Sci. Agr. **16**: 151–60. 1935.
290. ——— *et al.* Eradication of perennial weeds by the shallow cultivation methods. Univ. Sask., Agr. Ext. Bul. 100. 1940.
291. Pereira, H. C. Crop response to inter-row tillage. Emp. Jour. Exp. Agr. **9**: 29–42. 1941.
292. Pfeil, E. Untersuchungen über Zusammenhänge zwischen Natriumchloratwirkung und physikalischen Bodeneigenschaften. Landw. Jahrb. **87**: 647. 1939.
293. Piemeisel, R. L. Changes in weedy plant cover on cleared sagebrush land and their probable causes. U. S. Dept. Agr., Tech. Bul. 654. 1938.
294. Pieters, A. J. What is a weed? Jour. Am. Soc. Agron. **27**: 781–83. 1935.
295. Porter, D. R. Canada thistle and quack grass eradication. Ia. Agr. Exp. Sta., Ext. Bul. 113. 1924 (Revised).
296. Porter, R. H. and Sylvester, E. P. Noxious and other bad weeds in Iowa. Ia. Agr. Exp. Sta., Ext. Corc. 201. 1939 (Revised).
297. Rabaté, E. La destruction des ravenelles par l'acide sulfurique. Jour. d'Agr. Prat. **26**: 607. 1911.
298. ———. Nettoyage des champs de cereales par l'acide sulfurique. Jour. d'Agr. Prat. **35**: 110–12. 1921.
299. ———. Action de l'acide sulfurique contre la rouille du ble'. Compt. Rend. Acad. Agr. France **9**: 403–04. 1923.
300. ———. Action de l'acide sulfurique diluée dans les champs de céréales. Compt. Rend. **179**: 1285–87. 1924.
301. ———. L'emploi de l'acide sulfurique pour le contrôle des mauvaises herbes et des parasites. Int. Rev. Sci. Prac. Agr. **4**: 535–45. 1926.
302. ———. Action de l'acide sulfurique sur la terre cultivee. Jour. d'Agr. Prat. **47**: 215–17. 1927.

303. RADEMACHER, B. Die Stickstoffdüngung als spezifisches Mittel zur Bekäampfung der Unkrautwicken im Getreide. Pflanzenbau **16:** 182–201. 1939.
304. ————. Über den Lichteinfall bei Wintergetreide und Winteröl-früchten und seine Bedeutung für die Verunkrautung. Pflanzenbau **15:** 241–65. 1939.
305. ————. Über den antagonistischen Einfluss von Rogen und Weizen auf Keimung und Entwicklung mancher Unkräuter. Pflanzenbau **17**(5): 131–143. 1940. [Biol. Abs. 5217. Feb. 1942].
306. ————. The control of weeds in Germany. Imp. Bur. Past. & For. Crops, Herb. Pub. Ser., Bul. *27*: 68–112. 1940.
307. RATHER, H. C. Weed problems in relation to the production and marketing of farm seeds. Jour. Am. Soc. Agron. **22:** 409–16. 1930.
308. RAYNOR, R. N. The chemical control of St. Johnswort. Cal. Agr. Exp. Sta., Bul. 615. 1937.
309. REMY, T. AND VASTERS, J. Beobachtung über die Unkrautbekämpfung durch Kainit. Landw. Jahrb. **46:** 627–57. 1914.
310. REES, J. The use of sodium chlorate for destroying some perennial weeds. Welsh Jour. Agr. **14:** 277–80. 1938.
311. ROBBINS, W. W. Weed control in central Europe. Cal. Dept. Agr., Mo. Bul. **23** (2, 3, 4, 5, 6): 124–26. 1934.
312. ————. Weeds in orchards. Reclam. Era **31:** 147–50. 1941.
313. ———— *et al.* Weed control. 1942.
314. ROBERTSON, J. M. AND STEWART, A. B. Weed eradication in lawns by chemical treatment. Jour. Bd. Greenkeep. Res. **5:** 213–5. 1938.
315. ROGERS, C. F. Carbohydrate metabolism in the roots of Canada thistle, *Cirsium arvense* (L). Thesis, Iowa State College.
316. ————. Winter activity of the roots of perennial weeds. Science **69:** 299–300. 1929.
317. ———— AND HATFIELD, I. Carbon disulfide for the eradication of perennial weeds. Col. Agr. Exp. Sta., Bul. 347. 1929.
318. ROGERS, C. H. Cotton root-rot and weeds in native hay meadows of central Texas. Jour. Am. Soc. Agron. **28:** 820–23. 1936.
319. ROSENFELS, R. S. Whitetop control on the Newlands project in Nevada. Reclam. Era **31:** 47–50. 1941.
320. ———— AND CRAFTS, A. S. Arsenic fixation in relation to the sterilization of soils with sodium arsenite. Hilgardia **12:** 201–29. 1939.
321. ————, ————. Chlorate distribution and the effect of nitrate concentration on chlorate toxicity in soil columns. Hilgardia **14:** 71–79. 1941.
322. ROWLEY, H. K. When to treat quack grass most effectively with chlorates. Jour. Am. Soc. Agron. **23:** 41–2. 1931.
323. RUNNELS, H. A. AND SCHAFFNER, J. H. Manual of Ohio weeds. Ohio Agr. Exp. Sta., Bul. 475. 1931.
324. SALLANS, B. J. The relationship of weeds to losses caused by common root rot in wheat. Sci. Agr. **20:** 632–7. 1940.
325. SAMPSON, A. W. AND PARKER, K. W. St. Johnswort on range lands of California. Cal. Agr. Exp. Sta., Bul. 503. 1930.
326. ———— AND MALMATIN, A. E. Stock-poisoning plants of America. Cal. Agr. Exp. Sta., Bul. 593. 1935.
327. SANDHOFF, A. G. AND SKINNER, C. E. The nitrification of ammonium thiocyanate (a weed eradicant) and effect of this compound upon the soil population. Soil Sci. **48:** 287–94. 1939.
328. SCHAFER, E. G. The bindweed. Wash. Agr. Exp. Sta., Pop. Bul. 137. 1927.
329. ————. Eradicating the bindweed with sodium chlorate. Wash. Agr. Exp. Sta., Bul. 235: 1–16. 1929.
330. SCHWENDIMAN, A. The toxicity and decomposition of sodium chlorate in soils. Jour. Am. Soc. Agron. **33:** 522–37. 1941.

331. ———— *et al.* Chemicals control field bindweed and leafy spurge. Wis. Agr. Exp. Sta., Bul. 449, pp. 80, 81. 1940.
332. ———— *et al.* New chemical kills weeds but not grain. Wis. Agr. Exp. Sta., Bul. 451, pp. 18, 19. 1941.
333. SEDDON, H. R. AND MCGRATH, T. T. Toxicity of sodium chlorate. Agr. Gaz. New So. Wales **41:** 765–66. 1930.
334. SEVELEV, I. N. AND DOBROHLEB, I. F. Couch grass (*Agropyrum repens* P. B.) and its control. Dokl. Vsesojuz. Akad. S. H. Nauk. No. 9. 11–14. 1940. (Ukraine Inst. Grain Husb., Kiev). [Herb. Abs. **11:** No. 667. 1941].
335. SHEDD, C. K. *et al.* Weed control in growing corn. Ia. Agr. Exp. Sta., Bul. 44: 439–67. 1942.
336. SILVERSIDES, W. H. The rate and mode of penetration of herbicides. I. Copper nitrate solutions. Sci. Agr. **20:** 419–23. 1940.
337. SIMONDS, A. O. The anatomical development of *Lepidium draba.* Jour. Agr. Res. **57:** 917–28. 1938.
338. SINGH, B. N. AND DAS, K. Effectiveness of spraying with fertilizers for control of weeds on arable land. Jour. Am. Soc. Agron. **30:** 465–74. 1938.
339. ————, ————. Effectiveness of contact sprays in the control of annual weeds in cereal crops. Jour. Am. Soc. Agron. **31:** 200–208. 1939.
340. SIRRI, A. Come vincere la cuscuta [Dodder control]. Gior. Agr. Domen **47:** 233. 1937. [Herb. Abs. **7:** No. 4. 1937].
341. SJÖGREN. E. Kan maskrosens spridning förhindras? [Can the spreading of the dandelion be prevented?] Svensk Frötidn. **3:** 149. 1934. Herb. Abs. **5:** 295. 1935].
342. SKILBECK, D. AND COLES, H. G. Weed control by sulfuric acid spraying in France. Scot. Jour. Agr. **15:** 410–4. 1932.
343. SKIVER, C. E. Wild garlic and its control in Indiana. Purdue Agr. Ext. Sta., Lft. 167. 1933.
344. SMITH, C. A. NEAL. A preliminary investigation of the relative effectiveness of various chemicals in the control of some common weeds. Jour. Dept. Agr. So. Australia **41:** 921–31. 1938.
345. SMITH. C. W. Machinery to control the field bindweed. Agr. Eng. **16:** 142–8. 1935.
346. ————. Cultural control of bindweed. Agr. Eng. **21:** 468. 1940.
347. SMITH, E. V. AND FICK, GEO. L. Nut grass eradication studies: I. Relation of the life history of nut grass, *Cyperus rotundus* L. to possible methods of control. Jour. Am. Soc. Agron. **29:** 1007–13. 1937.
348. ———— AND MAYTON, E. L. Nut grass eradication studies: II. The eradication of nut grass, *Cyperus rotundus* L., by certain tillage experiments. Jour. Am. Soc. Agron. **30:** 18–21. 1938.
349. ————, ————. Nut grass eradication studies. III. The control of nut grass, *Cyperus rotundus* L., on several soil types by tillage. Jour. Am. Soc. Agron. **34:** 151–9. 1942.
350. SMITH, WM. G. Common weeds. Scot. Jour. Agr. **4:** 382–94. 1921.
351. SNIDOR, H. J. Probable effects of weeds on the fertility of soils. Ill. State Acad. Sci., Trans. **33:** 34–35. 1940.
352. SOURDILLE, P. Le traitement des blés à l'acide sulfurique et le sulfate d'ammoniaque. Compt. Rend. 6me réunion annuelle et 7me réunion du comptoir francais de l'azote. 21–25. 1926.
353. SPENCER, E. R. Just weeds. 1940.
354. SRB, J. V. *et al.* Cost of bindweed eradication by the tillage method. Jour. Am. Soc. Agron. **30:** 425–29. 1938.
355. STAHLER, L. M. Some ecological aspects of competition between crop plants and field bindweed. Thesis, Univ. Minn. 1941.
356. STAPP, C. AND BUCKSTEEG, W. Biologischer Nachweis von Chlorat im Boden. Arb. Biol. Reichsanst. **22:** 363–77. 1938.

357. STARK, F. L., JR. *et al.* Effect of chloropicrin fumigation on nitrification and ammonification in soil. Soil Sci. **48:** 433–42. 1939.
358. STEVENS, O. A. North Dakota weeds. No. Dak. Agr. Exp. Sta., Bul. 162. 1922.
359. ————. Poisonous plants and plant products. No. Dak. Agr. Exp. Sta., Bul. 265. 1933.
360. STEWART, G. AND PITTMAN, D. W. Ridding the land of wild morning glory. Utah Agr. Exp. Sta., Bul. 189. 1924.
361. ————, ————. Studies in the eradication of wild morning glory. Jour. Am. Soc. Agron. **16:** 506–18. 1924.
362. STEWART, R. T., *et al.* The spurge nettle. Jour. Am. Soc. Agron. **28:** 907–13. 1936.
363. STEYN, D. G. The most important poisonous plants of South Africa. Imp. Bur. Past. & For. Crops, Herb. Pub. Ser., Bul. 27: 158–62. 1940.
364. STITT, R. E. Dodder control in annual lespedezas. Jour. Am. Soc. Agron. **31:** 338–43. 1939.
365. STOA, T. E. *et al.* The control of quack-grass by tillage. No. Dak. Agr. Exp. Sta., Bul. 244: 1930.
366. STOKER, G. L. *et al.* The effect of different methods of storing chicken manure on the viability of certain weed seeds. Jour. Am. Soc. Agron. **26:** 600–09. 1934.
367. STURKIE, D. G. The influence of various top-cutting treatments on rootstocks of Johnson grass (*Sorghum halepense*). Jour. Am. Soc. Agron. **22:** 82–93. 1930.
368. ————. Control of weeds in lawns with calcium cyanamid. Jour. Am. Soc. Agron. **25:** 82–4. 1933.
369. ————. Control of weeds in lawns with calcium cyanamide. Jour. Am. Soc. Agron. **29:** 803–8. 1937.
370. STURTEVANT, E. L. Weeds in corn. N. Y. (Geneva) Agr. Exp. Sta., Ann. Rep. 5. 46. 1886.
371. TEHON, L. R. Rout the weeds. Ill. Nat. Hist. Survey, Circ. 28. 1937.
372. TEMPLETON, W. C., JR. AND RITCHER, P. O. Dandelion control with dichloroethyl ether. Jour. Am. Soc. Agron. **34:** 283–4. 1942.
373. THOMPSON, H. C. Experimental studies of cultivation of certain vegetable crops New York. Cornell Agr. Exp. Sta., Mem. 107: 1–73. 1927.
374. THORNTON, B. J. AND DURRELL, L. W. Colorado weeds. Col. Agr. Exp. Sta., Bul. 403. 1933.
375. TILDESLEY, W. T. A study of some ingredients found in ensilage juice and its effect on the vitality of certain weed seeds. Sci. Agr. **17:** 492–501. 1937.
376. TIMMONS, F. L. Methods of eradicating bindweed. Kan. St. Bd. Agr. 57: No. 226. 102–12. 1938.
377. ————. Results of bindweed control experiments at the Fort Hays Branch Station. Kan. Agr. Exp. Sta., Bul. 296. 1941.
378. TINCKER, M. A. H. Chemical weedkillers in relation to horticulture. Ann. App. Biol. **25:** 644–8. 1938.
379. TINGEY, D. C. The comparative cost and effectiveness of tillage and of chlorates in the control of morning glory, Canada thistle, and perennial sow thistle. Jour. Am. Soc. Agron. **26:** 864–76. 1934.
380. ———— AND MAGUIRE, B. Lawn weeds and their control. Utah Agr. Exp. Sta., Circ. 117. 1941.
381. TINLINE, M. J. Eradication of leafy spurge (*Euphorbia Esula*). Dept. Agr. Dom. Canada, Farm. Bul. 99. 1940.
382. TROWBRIDGE, P. F. *et al.* Studies of the timothy plant. II. Mo. Agr. Exp. Sta., Res. Bul. 20. 1915.
383. TUCKER, R. H. Control of noxious perennial weeds in Colorado. Col. Agr. Exp. Sta., Ext. Bul. 340–A. 1936.

384. VERCHÈRE, P. La destruction des chiendents [The destruction of couch grass]. Jour. Agr. Prat. **96**: 456–8. 1932.
385. VIGOR, S. H. Chemical weedkillers. Sci. Agr. **9**: 587–93. 1929.
386. WALKER, C. Watch quality in your dairy produce. New Zealand Jour. Agr. **62**: 235–8. 1941.
387. WALLACE, J. M. AND MURPHY, A. M. Studies on the epidemiology of curly top in southern Idaho, with special reference to sugar beets and weed hosts of the nector *Eutettix tenellus*. U. S. Dept. Agr., Tech. Bul. 624. 1938.
388. WARINGTON, KATHERINE. The influence of manuring on the weed flora of arable land. Jour. Ecol. **12**: 111–26. 1924.
389. ————. The effect of constant and fluctuating temperature on the germination of the weed seeds in arable soil. Jour. Ecol. **24**: 185–204. 1936.
390. WEAVER, G. H. Getting dandelions out of the lawn. Flower Grower **24**: 214–215. 1937.
391. WELTON, F. A. Sodium chlorate as a lawn weed killer. Ohio Agr. Exp. Sta., Bi. Bul. 141. 1929.
392. ———— *et al.* Organic food reserves in relation to the eradication of Canada thistle. Ohio Agr. Exp. Sta., Bul. 441. 1929.
393. ———— AND CARROLL, J. C. Renovation of an old lawn. Jour. Am. Soc. Agron. **26**: 486–91. 1934.
394. ————, ————. Crabgrass in relation to arsenicals. Jour. Am. Soc. Agron. **30**: 816–826. 1938.
395. ————, ————. Control of lawn weeds and the renovation of lawns. Ohio Agr. Exp. Sta., Bul. 619. 1941.
396. WESTGATE, W. A. AND RAYNOR, R. N. A new selective spray for the control of certain weeds. Cal. Agr. Exp. Sta., Bul. 634. 1940.
397. WIANT, D. E. AND PATTY, R. L. The two-row cultivator converted into a weed control machine. So. Dak. Agr. Exp. Sta., Bul. 303. 1936.
398. WILLARD, C. J. Killing field weeds with chlorates. Ohio Agr. Exp. Sta., Bi. Bul. 146: 158–168. 1930.
399. ———— AND LEWIS, R. D. Eradicating Canada thistle. Ohio Agr. Exp. Sta., Ext. Bul. 146. 1939.
400. WILSON, H. K. *et al.* Weeds and their control. Minn. Agr. Exp. Sta., Ext. Spec. Bul. 183. 1938.
401. ———— *et al.* Identification and judging crops-weeds-diseases. 1940.
402. ———— *et al.* Battling weeds on Minnesota farms. Minn. Agr. Exp. Sta., Bul. 363. 1942.
403. WIMER, D. C. AND HARLAND, M. B. The cultivation of corn. Ill. Agr. Exp. Sta., Bul. 259. 1925.
404. WOODS, J. J. Chemical weed control in lawns. Sci. Agr. **22**: 356–65. 1942.
405. WOODWARD, T. E. The viability of seeds as affected by the siloing process. Jour. Dairy Sci. **23**: 267–71. 1940.
406. YEAGER, A. F. AND CALAHAN, C. L. Control of poison ivy (*Rhus toxicodendron*) by spraying. Am. Soc. Hort. Sci., Proc. **41**: 234–36. 1942.
407. YOST, T. F. Homemade bindweed tools. Kan. State Bd. Agr., 1939.
408. ZAHNLEY, J. W. AND PICKET, W. F. Field bindweed and methods of control. Kan. Agr. Exp. Sta., Bul. 269. 1934.
409. ———— AND FITCH, J. B. Effect of ensiling on the viability of weed seeds. Jour. Am. Soc. Agron. **33**: 816–22. 1941.

Genetics of Neurospora	C. L. LINDEGREN *Washington University*
Protoplasmic Connections	L. G. LIVINGSTON *Harvard University*
Endomitosis	A. LORZ *Seton Hall College*
Tropical Fruits and Their Future	S. J. LYNCH *Sub-tropical Experiment Station*
Paleobotanical Taxonomy	H. L. MASON *University of California*
Cell-shape	E. B. MATZKE *Columbia University*
Plant Disease Introduction	W. A. MCCUBBIN *Bureau of Entomology and Plant Quarantine*
Plant Oils	J. B. MCNAIR *Field Museum, Chicago*
Recent Advances in the Science and Technique of Seed Analysis	R. H. PORTER *Iowa State College*
Polyploidy	L. F. RANDOLPH *Cornell University*
Distribution and Composition of Paleozoic Floras in North America	C. R. READ *U. S. Geological Survey*
Bacterial Galls	A. J. RIKER *University of Wisconsin*
Phylogeny of the Basidiomycetes	D. P. ROGERS *Brown University*
Cell Physiology	G. W. SCARTH *McGill University*
Botanical Contributions to the Study of Coal	J. M. SCHÖPF *Illinois State Geological Survey*
Air Space Tissue in Plants	H. B. SIFTON *University of Toronto*
Recent Developments of Taxonomic Agaricology	A. H. SMITH *University of Michigan*
History of Arctic and Alpine Floras	C. W. SHARSMITH *University of Minnesota*
Phytogeography of the Temperate West Coast of South America	H. E. STORK *Carleton College* and J. L. MORRISON *University of California*
Taxonomy of North American Fresh-Water Algae	L. H. TIFFANY *Northwestern University*
Nematode Diseases of Plants	A. L. TAYLOR *Bureau of Plant Industry*
Measurement of Soil Moisture	F. J. VEIHMEYER *University of California*
Control of Fungi in Lumber during Air-Seasoning	A. F. VERRALL
Utilization of Native Plants by the American Indians	P. A. VESTAL *Harvard University*
The St. Lawrence River as a Biological Habitat for Higher Plants	FR. MARIE-VICTORIN *University of Montreal*
Modern Views and Facts About Growth Substances	P. W. ZIMMERMAN *Boyce Thompson Institute for Plant Research*

Proposed Future Contents of
THE BOTANICAL REVIEW

Articles received and awaiting publication

Recent Studies on the Inheritance of Size and Shape in Plants	H. H. SMITH *Bureau of Plant Industry*
Radiation and Plant Respiration	R. L. WEINTRAUB *Smithsonian Institution*
Plant Microfossils	L. R. WILSON *Coe College*
Fungus and Bacterial Diseases of Insects as Factors in Biological Control	H. S. FAWCETT *University of California Citrus Experiment Station*
Heterosis	W. G. WHALEY *Barnard College*
Antibiotic Substances Derived from Micro-organisms	J. C. HOOGERHEIDE *Corsan Research Laboratories*

Articles arranged for most recently

Role of the Endosperm in Seed Development	R. A. BRINK *University of Wisconsin*
Genetics and Cytology of Forage Grasses	W. M. MYERS *Pennsylvania State College*
Vegetable Seed Treatment	J. C. WALKER *University of Wisconsin*

Articles in course of preparation

The Cytology of Fertilization in Angiosperms	L. E. ANDERSON *Duke University*
Development of the Madro-Tertiary Flora	D. I. AXELROD *University of California*
Relation of Wood Anatomy to Taxonomy	I. W. BAILEY *Harvard University*
Anthocyanin Pigments	F. BLANK *Switzerland*
The Genetics of Pollen Tube Growth	J. T. BUCHHOLZ *University of Illinois*
Sexuality and Genetics of Algae	H. BOLD and W. G. WHALEY *Columbia University*
The Angiosperm Embryo Sac	EMMA L. FISK *University of Wisconsin*
The Male Gametophyte of Angiosperms	A. GERSHOY *University of Vermont*
Cytogenetics of Nicotiana	T. H. GOODSPEED *University of California*
Tundra Vegetation	R. F. GRIGGS
American Agar Industry	H. J. HEMM *Duke Marine Laboratory*
Laboratory Testing of Spraying and Dusting Fungicides	J. G. HORSFALL *Connecticut Agriculture Experiment Station*
Cytology and Genetics in Relation to Taxonomy	C. L. HUSKINS *McGill University*
A Critical Survey of the Present Status of Plant Embryology	D. A. JOHANSEN *Stanford University, Cal.*
Techniques for Aseptic Growth of Plants	L. C. KNORR *Cornell University*

(Continued inside)